NOAA National Weather Service

NextGen Architecture
and Infrastructure Development

Weather Information Database (WIDB)
Information Technology System Architecture Document
Initial Draft Version 0.2

Re: Task 3.2.1.1 of GSA Schedule Order DG133W-09-NC-0492
(GSA Schedule No. GS23F0286P)

Provided to NOAA National Weather Service

Provided by Skjei Telecom, Inc.

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1 Executive Summary

The Cube will be implemented as a virtual network of databases, consisting of a set of distinct data repositories located in different geographical locations accessible via network enabled web services. Operations of the Cube will also support the Single Authoritative System (SAS), which will provide users with a single point for approved, authoritative aviation weather information. Independently managed data sources will be under the control of the owning agents such as NOAA, FAA, DoD, and possibly other Government and commercial weather information providers.

The NOAA IT architecture will follow a Web Services-enabled, SOA-based System of Systems design approach in the implementation of its inter-enterprise application integration. Systems-of-Systems are defined by the independence of their respective components, their evolutionary nature, emergent behaviors, and a geographic extent that limits the direct interaction of their components to exchange information. The SOA-based nature of the approach makes use of a federated registry/repository that allows for the discovery of supported Cube services and their respective metadata, and the weather products and data sets these services provide.

The NOAA IT architecture development steps include:

1. Derivation of functional and performance IT requirements
2. Identification of weather products/data sets required for inclusion in Cube and their respective data formats
3. Identification of candidate systems for inclusion in Cube
4. Identification of Web Services used to enable network-enabled access to Cube products and resultant data exchange formats
5. Development of an overall architecture required to support access to Cube weather products from candidate systems, via Web services and data exchange formats, while abiding by key functional and performance requirements, and remaining compatible with efforts of other Cube participants

The following key assumptions are driving NOAA's NextGen IT Architecture:

- Use of a System of Systems approach
- Compatibility with key NOAA and NWS Enterprise Architecture guidance
- Compliance with NextGen requirements
- Supports IT ConOps Use Cases
- Compatible with evolving FAA Architecture
- Supportive of NextGen Enterprise Architecture definition of Business Services / Operational Activities

The weather products and datasets required to be included in the Cube are defined in the NextGen EI team's *IOC Product List,* which is supplemented with the FAA generated-*IOC Product Flow Sheet*. From those source documents, the NOAA and FAA systems required to be included as part of the Cube to serve as producers and consumers of these Cube products can begin to be identified. Appendix B describes the Concept of Operations and Technology Architecture of these candidate NOAA and FAA systems and the key information flows amongst these systems.

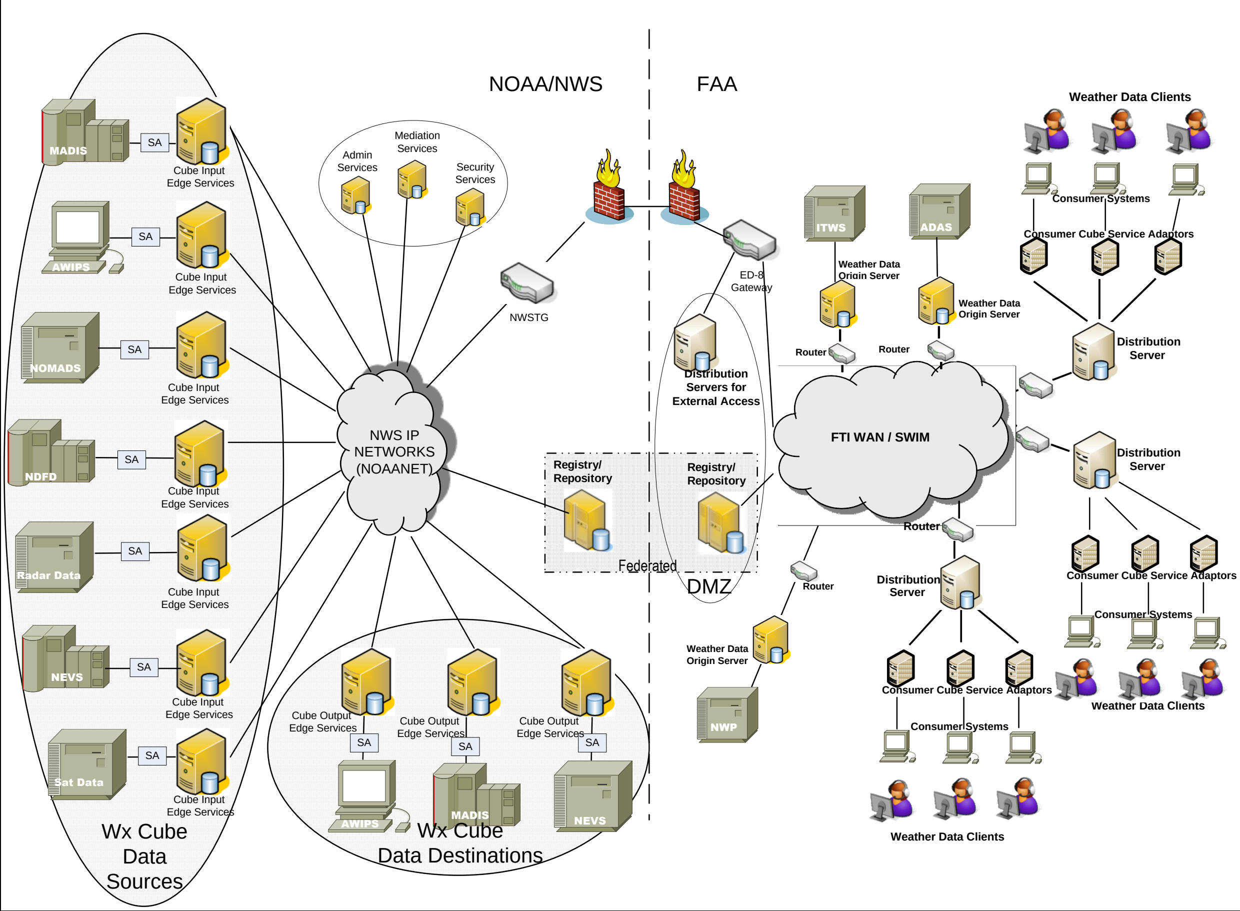
The IT architecture framework is comprised of four layers

1. Telecommunications Infrastructure Layer - provides the network connectivity and associated monitoring infrastructure which consists of a secure Internet Protocol (IP) network, with standard naming and addressing management, routine network incident detection and response, and identity management.
2. Core Services Layer - ensures the interoperability of and allows the network enabling via web services through the use of open standards (HTTP, XML, REST, SOAP, etc)
3. Weather Services Layer – addresses the weather domain concerns of the Cube
4. Application Layer - consists of weather data users and systems that will provide data to and consume data from the Cube

Network-enabling of NOAA systems involved in the Cube will be performed via Cube Input Edge Services (CIES) and Cube Output Edge Services (COES) as shown in the figure below.

- Cube Input Edge Services (CIES)
    - Provides for the ingest of weather data required by the Cube (obtained either directly from the native source or via a Service Adaptor (SA))
    - Performs the necessary processing and local storage
    - Allows remote access to the weather data (or subsets thereof) via WCS/WFS/JMBL/other web services.
- Cube Output Edge Services (COES)
    - Provides for the request and retrieval of Cube data from remote WCS/WFS/JMBL/other web services
    - Performs the necessary processing
    - Allows access to the data by the requesting local destination system (via Service Adaptors (SA)).

CROSS ORGANIZATIONAL NOTIONAL ARCHITECTURE



Alternative implementations allow for redundant CIES/COES (where multiple CIES/COES may interface to a single supporting data source or destination system), or shared CIES/COES (where multiple data source or destination systems may share a single CIES or COES).

The CIES/COES perform a variety of functional activities, including:

- General system management
- Platform management
- Data access / storage management
- Enterprise support / management
- Wx Data request management
    - For Query / reply requests
    - For Subscription service requests
- Security
- Discoverability management

To ensure cross-organizational compatible, Web Service interfaces such as OGC's WCS/WFS standards are being considered, along with the DoD's JMBL implementation. Additionally, gridded data exchange formats such as NetCDF4 (and GRIB2), and non-gridded XML-based data exchange formats such as WXXM (and JMBL) are being considered. A Registry/Repository solution that allows for cross-organization federation of discoverable service information has also been incorporated into the baseline architecture. A number of other potential standards related to SOA technologies, web services, and weather data representation are being considered and are addressed in a separate appendix.

Various other shared or stand-alone services may also be required to support NOAA's cube responsibilities, including:

- Administrative Services – which allow for the overview management, monitoring, configuration and operations of the overall Cube components
- Security Services – which perform security functions associated with the Cube
- Mediation Services – which are used to maintain interoperability between otherwise incompatible data formats or data exchange protocols

A number of open issues still remain, which include:

- Use of FAA-developed reference implementation as baseline for NOAA's CIES/COES (and resulting impact of the OGC-based, non-JMBL approach, that makes use of Oracle as its core database)
- Inclusion of textual / graphical weather products in the Cube, and the appropriate Web Service to support such product formats
- Determining more, and better requirements (i.e., performance and security requirements) and associated use cases and their inclusion in a final architecture / design solution
- Physical network considerations, including NOAANET to FTI connectivity
- Determining definitive source systems for each Cube product
- Determining weather product / dataset sizes to assess network bandwidth/throughput needs
- Determining data exchange formats for each weather product

2 Introduction

2.1 Background

NextGen is focusing on a major new direction in aviation weather information capabilities to help stakeholders at all levels make better decisions in hazardous weather situations. NextGen-era aviation operations will be dependent on enhanced aviation weather capabilities based on three tenets:

- A common picture of all weather for all air transportation decision-makers and aviation system users
- Weather directly integrated into sophisticated decision support capabilities to assist decision-makers
- Utilization of Internet-like information dissemination capabilities to realize flexible and cost-efficient access to all necessary weather information

To this end, development and implementation of the NextGen Weather Cube is required. The Cube will enable the access to all digital weather information needed by NextGen aviation needs. The Cube will be implemented as a virtual network of databases, consisting of a set of distinct data repositories located in different geographical locations accessible via network enabled web services. The guiding concept behind the Cube is to provide a common access point for aviation users to access aviation weather information and data from multiple data providers and sources. The Cube will be implemented as a net-centric, distributed set of weather services. Operations of the Cube will also support the Single Authoritative System (SAS), which will provide users with a single point for approved, authoritative aviation weather information.

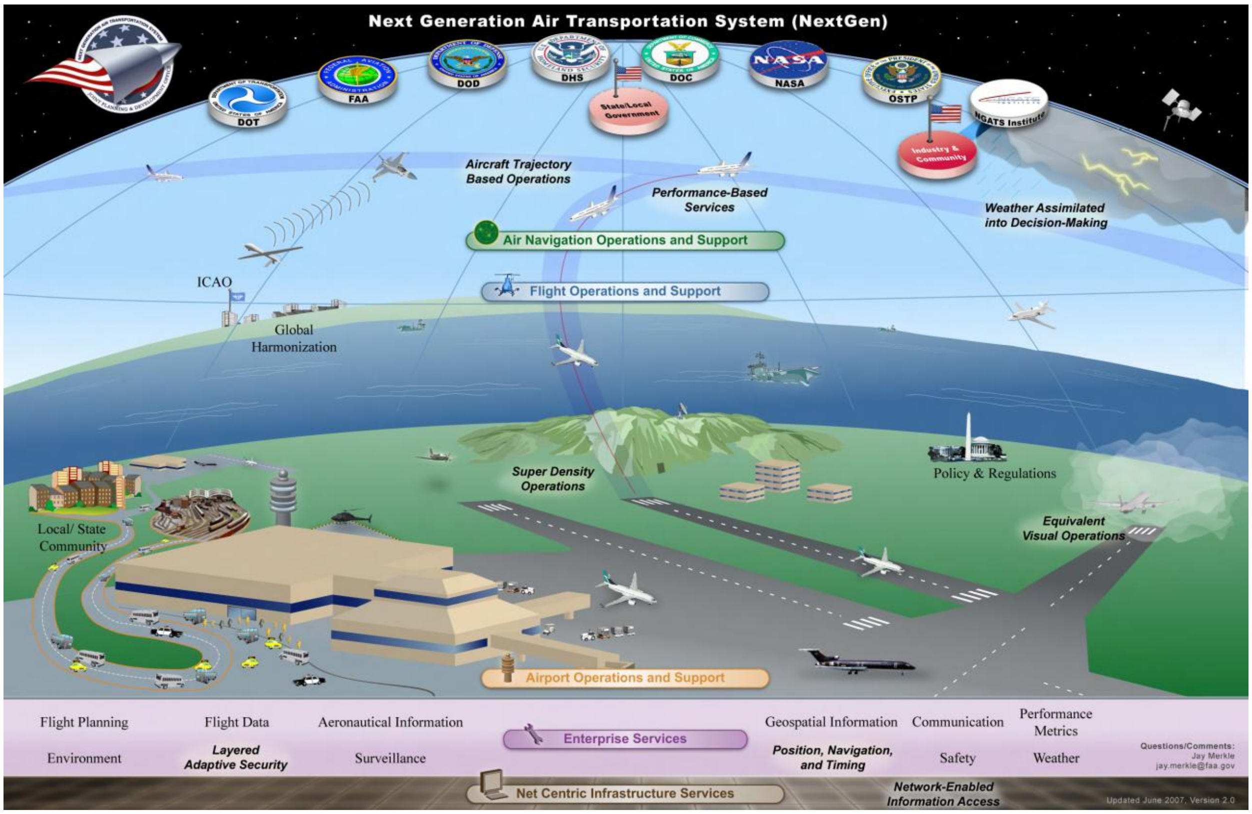
2.2 Purpose

The IT architecture addressed within this document presents an approach that NOAA NWS can implement to fulfill its obligation to develop the 4-D Weather Cube in support of JPDO and FAA NextGen weather requirements, as well as internal NOAA NWS requirements. The Cube itself is not being developed solely by NOAA NWS, rather it will be a federation of network-enabled services, some already existing, and some yet to be developed, and will be developed in close coordination with the FAA and the JPDO and its other members. The document is intended to assist in this coordination effort.

The concept is that NOAA NWS will implement its side of the Cube to ingest and subsequently serve out weather information and data of interest to the aviation community using a distributed, net-centric architecture that will interact with the complementary systems architecture being developed by the FAA. Ingested data will come from a wide range of data providers within NOAA and NWS, as well as some external sources.

2.3 Key Players

The distributed nature of weather data makes the Cube a virtual database that will be composed of multiple, physical databases maintained at different locations. These independently managed data sources will be under the control of the owning agents such as NOAA, FAA, DoD, and possibly other Government and commercial weather information providers. Through the use of a network-centric architecture built on SOA principles, the Cube will function and appear to users as a single database. The actual physical locations of the data sources will be transparent to the users. This distributed service model is in keeping with the net-centric dissemination vision of NextGen. This weather data will be made available for use by any and all participants across the NextGen Air Transportation system depicted in the figure below in support of their various missions and responsibilities.



2.4 Architecture Development Process

The steps being followed in the development of the IT architecture are generalized below:

1. Derivation of functional and performance requirements from key program documents
2. Identification of weather products/data sets required for inclusion in Cube
3. Identification of likely candidate systems for inclusion in Cube to provide / access Cube weather products
4. Identification of Web Services used to enable network-enabled access to Cube products and resultant data exchange formats
5. Development of an overall architecture required to support access to Cube weather products from candidate systems, via Web services and data exchange formats, while abiding by key

functional and performance requirements, and remaining compatible with efforts of other Cube participants

A companion document to this one, the IT System Design Document, addresses the specific design to the level of detail necessary to realize the implementation of the concepts called out in the IT System Architecture Document.

3 Reference Documents

3.1 NextGen Reference Documents

The following NextGen documents were used in the preparation of the NOAA IT Architecture.

Document Name	Version	Date	Source
Concept of Operations for the Next Generation Air Transportation System	V2.0	6/13/2007	JPDO
NextGen Network-Enabled Weather IT CONOPS	3.2	8/20/2008	NCAR, MITLL, NOAA/GSD
NextGen ATS Enterprise Architecture	V2.0	6/22/2007	JPDO
Next Generation Air Transportation System Integrated Work Plan	V1.0	9/30/2008	On JPDO website
Next Generation Air Transportation System Integrated Plan			JPDO
Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management	0.1	1/18/2008	JPDO Functional Rqmts Study Team
Weather Concept of Operations	V1.0	5/13/2006	JPDO Weather Integrated Product Team
NextGen Weather Plan	0.6	3/20/2009	JPDO
List of IOC and FOC products that NWS has committed to provide for NextGen			JPDO EI Team
Final Performance Requirements (iFR) First Working Draft Wrapper - 4-D Weather Data Cube SAS	Draft	2/11/2009	JDPO
NextGen Business Case	V1.0	8/24/2007	JPDO
JPDO Information Management and Exchange Strategy	Draft	1/1/2008	JPDO
NextGen Weather Information Database - Information Technology Needs (Draft SON)	Draft	3/13/2009	OST
Concept of Operations and Operational Requirements - WIDB for the NextGen 07-042		5/4/2009	Office of Climate, Water and Weather Services
Definition of 4-D SAS		6/17/2009	NEWP presentation by JPDO Wx Policy Team2
ATM Wx Integration Plan	Draft V0.7	4/22/2009	JPDO
NextGen Network Enabled Weather Program 4-D Weather Cube White Paper	Ver 2.0	April 3, 2009	
4-Dimensional Weather Data Cube Web Feature Service Reference Implementation (WFSRI) Requirements	Ver 1.1	4/24/2009	GSD/NCAR/MITLL
4-Dimensional Weather Data Cube Web Coverage Service Reference Implementation (WCSRI) Requirements	Ver 1.1	3/23/3009	GSD/NCAR/MITLL
4-Dimensional Weather Data Cube Web Feature Service Reference Implementation (WFSRI) Architecture and Design	Ver 1.0	5/6/2009	GSD/NCAR/MITLL
4-Dimensional Weather Data Cube Web Coverage Service Reference Implementation (WCSRI) Architecture and Design	Ver 1.0	4/30/2009	GSD/NCAR/MITLL

NextGen Weather Data Flow and 4-D Weather Data Cube Service Adaptor Plan document	Draft	5/15/2009	FAA
FAA-developed IOC Product Flows worksheet			
NextGen Network-Enabled Weather Metadata Guidelines for the 4-D Weather Data Cube		4/24/2009	MITLL
NAS Architecture Roadmap	Ver 0.5	December 26, 2007	FAA
NAS Weather Functional Analysis Workgroup Report		August 30, 2004	FAA ATO
MITRE convection report			MITRE CAASD
4D Weather Cube Single Authoritative Source (SAS) Final Performance Requirements (fPR)	Ver 1.0	Sept 30, 2009	FAA
NextGen NCO Concept of Operations	Pre-Workshop Draft	Oct 1, 2009	JPDO

3.2 Standards-Related Reference Documents

The following standards-related documents were used or considered in the preparation of the NOAA IT Architecture.

Document Name	Version	Date	Source
WCS Implementation Standard	1.1.2	3/19/2008	OGC
WFS Implementation Specification	1.1.0	5/3/2005	OGC
Reference Architecture for Service Oriented Architecture	1	April 2008	OASIS
Reference Model for Service Oriented Architecture	1	October 2006	OASIS
NOAA Enterprise Architecture Technical Reference Model	V1.0	9/1/2007	NOAA
ISE Enterprise Architecture Framework	V2.0	Sept 2008	PM-ISE
DoD Architectural Framework DoDAF	v1.5	4/23/2007	DoD
Federal Enterprise Architectural Framework (FEAF)	V1.1	Sept 1999	CIO Council
NAS Enterprise Architecture Framework (NASEAF)	V 2.0	9/30/2007	ATO AF WG
NWS Enterprise Architecture			
National Interchange Exchange Model (NIEM)			

4 System of Systems

4.1 System of Systems (SoS) Overview

NextGen's vision will be achieved by having numerous systems interoperate. At this point, many communication links are point-to-point between systems. With a system-of-systems approach, all systems involved have access to all other systems. This distinction enables true interoperability and dynamic changes and overall performance can be achieved with relative ease when compared to changing multiple point-to-point links. In the NextGen era, the magnitude and complexity of the systems involved makes choosing SoS an easy choice to make. Therefore, NOAA has chosen this approach on which to build its Cube architecture.

There are five characteristics useful in distinguishing a true SoS from a large, complex but monolithic system.

1. Operational Independence of the Elements: If the system-of-systems is decomposed into its component systems, those component systems must be able to operate independently. The system-of-systems is composed of systems which are independent and useful in their own right.
2. Managerial Independence of the Elements: The component systems not only *can* operate independently, they *do* operate independently. The component systems are separately acquired and integrated but maintain a continuing operational existence independent of the system-of-systems.
3. Evolutionary Development: The system-of-systems does not appear fully formed. Its development and existence is evolutionary with functions and purposes added, removed, and modified with experience. Another perspective on this is that a system-of-systems is by definition scalable.
4. Emergent Behavior: The system performs functions and carries out purposes that do not reside in any component system. These behaviors are emergent properties of the entire system-of-systems and cannot be localized to any component system. The principal purposes of the system-of-systems are fulfilled by these behaviors. The system achieves such flexibility by leveraging upon agreed communication standards between systems.
5. Geographic Distribution: The geographic extent of the component systems is large. 'Large' is a nebulous and relative concept as communication capabilities increase, but at a minimum it means that the components can readily exchange only information.

Independent systems communicate with each other and leverage their functionality by implementing a service-oriented architecture (SOA) via Web Services a network-enabled System of Systems solution can be developed.

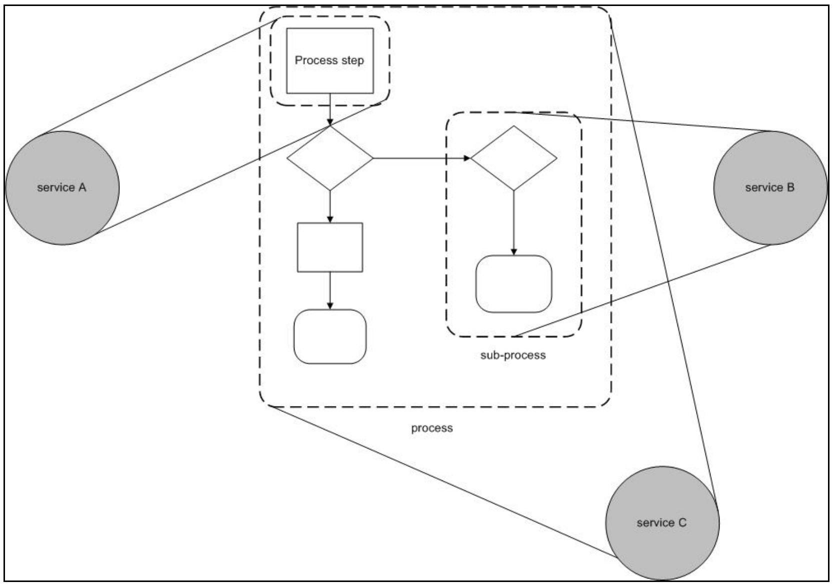
4.2 SOA Overview

4.2.1 Introduction to Services

Understanding how services play a role in SOA is key in establishing the connection between SOA and SoS.

The term "service-oriented architecture" represents a model in which automation logic is decomposed into smaller, distinct units of logic. These units can comprise a larger piece of business automation logic, and individually, these units can be distributed. In an SOA context, these units of logic are known as services.

Services encapsulate logic within a distinct context. This context can be for a specific business task/business rule. Services can also address a small or large concern; therefore the scope of a service can vary greatly. Further, services can encompass logic provided by other services. For example, a business process can be comprised of logic, which can be decomposed into a series of steps that execute in a specific sequence according to business rules. This is illustrated in the figure below.

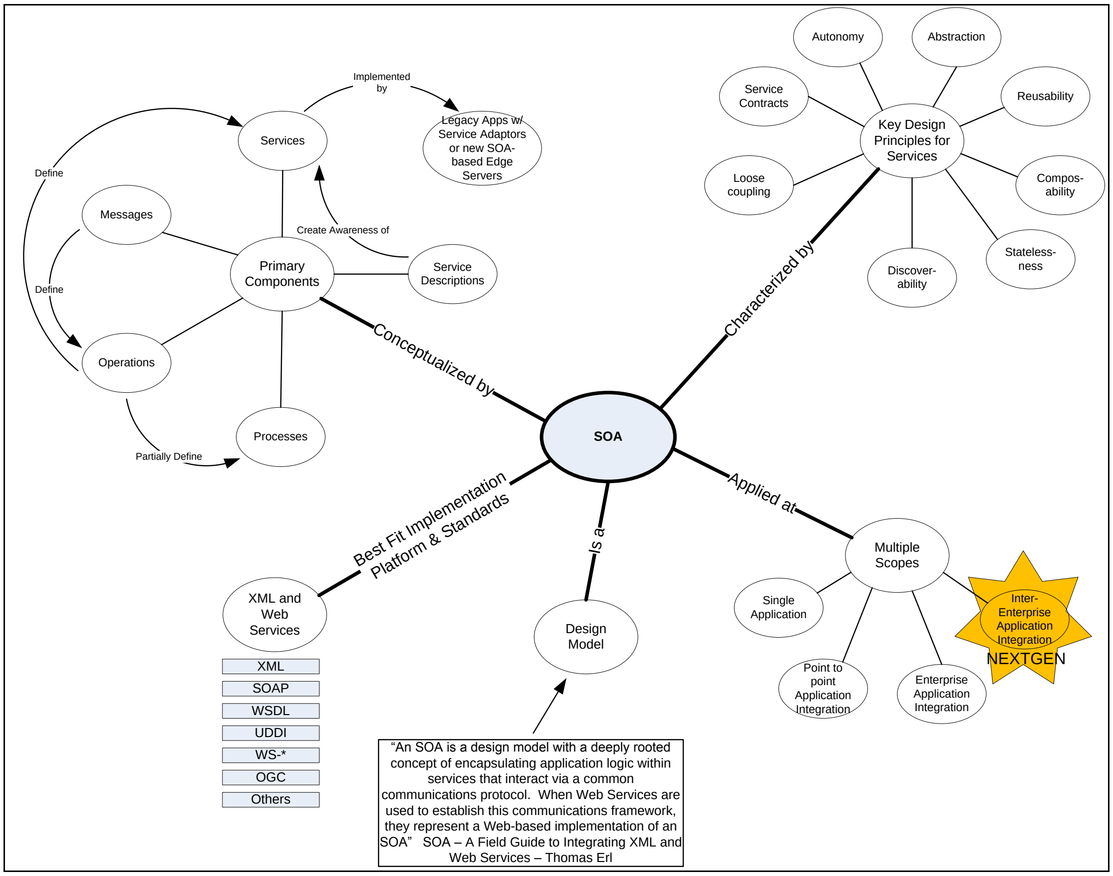


Depiction of how services encapsulate logic, and how services can be composed of other services.

The above figure shows how service C is composed of services A and B. In an SOA, services can be used by other services because they are aware of each through the use of *service descriptions.* A service description establishes the name and location (URN or URI) of the service, as well as its data exchange requirements. The use of service descriptions with services results in a relationship known as *loosely coupled*. Having loosely coupled services is fundamental to a SOA.

For services to interact and actually accomplish something meaningful, they must exchange information. The manner in which services exchange information is called *messaging*. The messaging framework must be standardized so that all services, regardless of origin, use the same format and transport protocol. This leads to an architectural design constraint. Additionally, within SOAs, emphasis is placed on the message design that an increasing amount of business and application logic is embedded into messages. In fact, the receipt of a message by a service is the most fundamental action within SOA and the sole action that initiates service-oriented automation. This places further demand on the messaging framework to be extremely flexible and highly extensible.

A System of Systems is by nature net-centric, providing transparency in the discoverability of available services. Its enabling framework is based on SOA design principles, which are graphically represented in the figure below.



Specifically, the following design principles are being incorporated in the development of the architecture.

- Service loose coupling – Services will maintain a relationship that minimizes dependencies and only requires that they maintain an awareness of each other
- Service contract – Services will adhere to a communications agreement, as defined collectively by jointly agreed to service description documents
- Service autonomy – Services will have full control over the logic they encapsulate
- Service abstraction – Services will hide logic from the outside world
- Service reusability – Logic will be divided into services with the intention of promoting reuse, where appropriate
- Service composability – The collections of resultant services will be coordinated and assembled to form composite services
- Service statelessness – Each request of a service will be independent of any previous service interactions.
- Service discoverability – Services will be outwardly descriptive so that they can be found and accessed via available discovery mechanisms

To connect these principles to a service-oriented solution an implementation platform is required. *Web Services* technology offers such a platform.

4.2.2 Web Service Basics

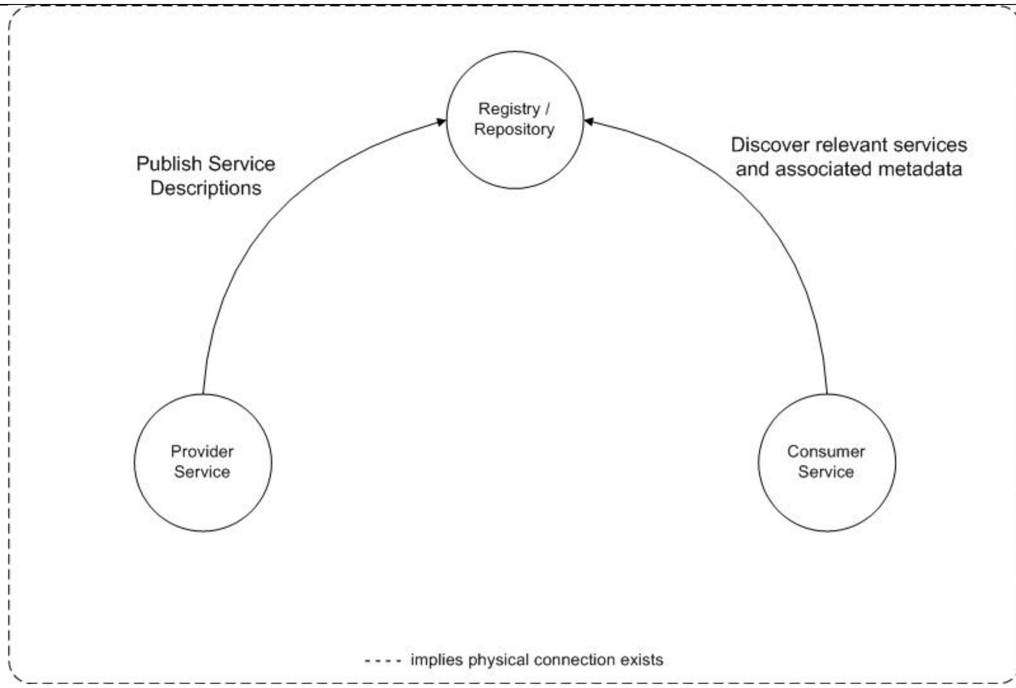
Web Services are used to achieve integration and interoperability between multiple systems. In general, systems are complex and in all likelihood have incompatible applications written in different programming languages. A layer of abstraction can be added through the XML layer represented by Web Services, and these systems that were not originally designed to work together now have a mechanism to interoperate.

Web Services make up a connection technology. It is a way to connect services together into a service-oriented architecture. To clarify, there is a difference between "services" and "Web services". The term *Web Services* refers to the technologies that allow for making connections. *Services* are connected together using Web Services. Typically, Web service messages are wrapped in an SOAP envelope and transmitted via HTTP.

Using Web Services as the basis for integration, data is converted into a canonical format understood by everyone (e.g., in NextGen's case, a complex XML schema – JMBL/WXXM), and messages are passed from one endpoint to another in that standard format. The respective endpoints are responsible for converting its native data types and formats to the agreed upon XML format when sending a message, and for converting XML data types into its native data types and formats when receiving a message. These conversions are done via Service Adaptors.

4.2.3 Bridging the Gap to SoS

Services and service descriptions are really only useful if all the systems in a SoS can discover them. This is where the *Registry/Repository* appears. Simply speaking, a registry holds references to 'things' and the repository holds those 'things'. In an SOA, service descriptions are the repository 'things' and the registry houses information about the service descriptions (metadata). The figure below shows a high-level view of how a consumer service can discover services through the registry/repository.



Depiction of how services utilize the reg/rep as a means of publishing and discovering services.

The only thing left is to define standards on the format of these services among the participating systems involved in a SoS. An agreed upon set of communication standards is necessary to ensure services are compatible. To establish such standards requires analyzing the type of data being exchanged to ultimately develop a well-defined way to represent the data in the messages. This applies to any message sent between services.

It is important for the representation of the data to be both highly flexible and extensible.

It is a considerable hurdle to try to create this 'agreed upon communication standard' because the independent systems need to coordinate/cooperate to develop it. Once the communication standards are developed, and a physical connection exists, the independent systems now have a means of leveraging other systems functionality via services in an SOA implemented by Web services.

The goal of this Architecture document is to present how these SOA concepts are to be combined to address the specific functionality required by the NextGen Cube.

5 Weather Cube Products / Systems

Core to the operation of the NextGen Wx Cube is the discovery, access, and exchange of weather elements used directly and indirectly for making aviation decisions. This weather information comes in many different forms. It includes all relevant aviation weather information (e.g., observations, automated gridded products, models, climatological data, and human-produced forecasts from public and private sources). The Wx Data Cube is composed of text products, graphic products, and machine readable products. It contains proprietary products and those in the public domain, as well as domestic and foreign weather information.

5.1 Products / Datasets

NOAA, NWS and its comprising organizations produce a large percentage of the weather products/data, as well as takes in products/data from other sources in order to perform its weather forecasting responsibilities in supporting aviation decision-making.

The table below is a representative list of weather products/data sets that have been identified for inclusion in the Cube. The reader should refer to the EI Team managed *IOC Product List* as the definitive document addressing identified NextGen products, as well as the FAA generated-*IOC Product Flow Sheet* which also depicts NOAA products and their FAA consuming or producing system, and in some cases, more details on the specific products and formats. The table below also captures, if currently known, the recommended source system for each weather product / data set as well as those systems that will mostly likely make use of this weather information. Efforts are underway to identify additional Wx products, their sources, and destination systems for each weather element.

	Weather Products / Data Sets	Source System(s)	Destination System(s)
NOAA Provided (Cube Input)	GOES E/W Imager Data	NESDIS ESPC / GSD?	NWP, NIDS
	POES imagery data	NESDIC ESPC / GSD?	
	METSAT data	NESDIS ESPC	NIDS
	TAFs	AWIPS/NWSTG/ADDS	NIDS
	METARS/SPECIs	MADIS	NWP, FDP2K, NIDS
	SIGMETs	AWIPS/ADDS	FDP2K, NIDS
	AIRMETs	AWIPS/ADDS	FDP2K, NIDS
	G-SIGMETs	ADDS	
	G-AIRMETs	ADDS	
	Surface Fronts	NWSTG	NIDS
	Meso-scale Boundaries		
	0-2 hour boundaries		
	2-8 hour boundaries		
	3-D Reflectivity	NSSL NMQ?	
	CCFP	ADDS	
	CWA	ADDS	NWP, NIDS
	MIS	ADDS	NWP, NIDS

	LAMP		
	Tropical Cyclone Bulletins		NIDS
	FA		NIDS
	Tornado Watch/Warning		NIDS
	Severe Thunderstorm Watch/Warning		NIDS
	Convective Outlook		NIDS
	Non-convective watches, warnings, advisories		NIDS
	Freezing Level Analysis		NIDS
	Surface Analysis		
	High Level Sig Wx		
	Mid Level Sig Wx		
	Low Level Sig Wx Charts		
	Winds Aloft		NIDS
	RUC	NCEP (NOMADS?)	ITWS, URET/DSR, CAPER, NWP
	WRF RR (winds/temps)	NCEP (NOMADS?)	NWP, ERAM, ITWS
	HRRR (15 min VIL, 15 min echo tops)	NCEP (NOMADS?)	NWP, ITWS
	Cb Tops		
	Cb Extent		
	Maximum and Average Clear Air Turbulence		
	Maximum and Average Icing Level		
	Maximum and Average in-cloud Turbulence		
	NCWF		NWP
	NCWD		NWP
	GTG	ADDS	
	GTG-2	ADDS	
	GTG (analysis)	ADDS	
	GTG-N (analysis)	ADDS	
	FIP	ADDS	
	CIP	ADDS	NWP
	National C&V forecast	ADDS	
	National C&V analysis	ADDS	
	Global wind grids		
	NEXRAD level II base data	NWSTG	
	NEXRAD level III products	NWSTG / RIDGE2	NWP, ITWS, NIDS
	NEXRAD data quality status		
	Radar Mosaics	NSSL NMQ	NIDS
	NWS graphic data products		NIDS
	NOAA 1 min ASOS Obs		
	MADIS Data (including MDCRS data, Mesonet, Maritime)	MADIS	NWP, ITWS, NIDS
NOAA Consumed	TDWR level II base data	TDWR/ITWS	
	TDWR level II products	TDWR/ITWS	

(Cube Output)	Radar Mosaics	WARP/NWP	
	FAA 1 min ASOS data	AWOS/ASOS/ADAS/RASP	MADIS?
	Lightning Data (including NALDN/NAPLN)	NDLN	NWP, ITWS, RASP
	Canadian Radar base data		NWP
	Mexican Radar base data		
	MDCRS EDR	ACARS/MDCRS	NCEP, MADIS
	PIREPs		
	METARS/SPECIs	RASP	MADIS
	5-120 min Storm VIL	NWP (CIWS)	?
	5-120 min Echo Tops	NWP (CIWS)	
	5-120 min Probability of Snow	NWP (CIWS)	
	5-120 min Verification	NWP (CIWS)	
	5-120 min Forecast Uncertainty	NWP (CIWS)	
	5-120 min Weather Avoidance Fields	NWP (CIWS)	
	2-8 hour Storm VIL	COSPA	
	2-8 hour Echo Tops	COSPA	
	2-8 hour Forecast Uncertainty	COSPA	
	2-8 hour Weather Avoidance Fields	COSPA	
	2-8 hour Probability of Snow	COSPA	
	2-8 hour Verification	COSPA	
	Hi-Res VIL Mosaic	COSPA	
	Hi-Res Echo Tops	NWP (CIWS)	
	Growth and Decay Trends	NWP (CIWS)	
	Storm Motion	NWP (CIWS)	
	Echo Tops Tags	NWP (CIWS)	
	Probability of Snow Analysis	NWP (CIWS)	
	Windowed lightning flashes	NWP (CIWS)	
	Wind – Diagnostics / Observations	LLWAS/ITWS	

The products presented below do not currently appear in the most recent version of the IOC Product list, but have appeared or been discussed as other potential candidate products for inclusion in the Cube.

	Weather Products / Data Sets	Source System(s)	Destination System(s)
NOAA Provided (Cube Input)	GIS system products	GIS system	
	UKMET model data		NWP, ATOP
	PRI (Puerto Rico) model data		ITWS
	STMAS model data		
	NAM V and NAM R model data	NCEP (NOMADS?)	NWP, FDP2K
	Climatology data	NCDC	
	GFS model data		NWP, ATOP, DOTS+
	Numerous other text and graphical based		NIDS

	NWS provided products		
	IOOS products		
	Verification statistics	NEVS, Stats on Demand, RTVS, NDFD	

5.2 Candidate Systems for Cube Inclusion

As they become identified and refined, the tables above will present the likely source system, and key destination systems associated with each product/dataset envisioned for initial NextGen deployment. NOAA has many internal exchanges of data/products as well. These are not shown in this table; since the purpose of the table is to characterize the input-output relationship of NOAA related products with respect to the 4-D Weather Cube. In some cases, it may be possible that a weather product can be obtained from multiple source systems. This table attempts to identify the most likely source for each product for inclusion into the Cube. These source systems are the resultant initial Candidate systems for inclusion into the Cube. Additional products/datasets required to support aviation needs may also be identified or new products/datasets may be developed, resulting in additional source systems that may need to be considered to inclusion with the NextGen infrastructure over time.

Although the final mapping between products and source/destination systems has not yet been completed and will likely continue to evolve, based on initial analysis, the following NOAA systems are envisioned as potential candidates for inclusion in the Weather Cube:

- ADDS - Consolidated Aviation Web Services (CAWS)
- AWIPS
- IOOS
- MADIS
- NCDC/NGDC
- NCEP CCS and NOMADS
- NDFD
- NDE (NPP/NPOESS)
- Verification Systems
    - NEVS
    - RTVS
    - Stats on Demand
- Radar Data Server
- TOC
    - TG/NDGD/NOAANET
- Web Farms
- GAS (GOES-R)
- NSSL NMQ
- Ridge 2 Server
- Others?

Appendix B describes the Concept of Operations and Technology Architecture for many of these candidate NOAA systems and FAA systems addressed above for each Cube weather product, and includes key information flows amongst these systems.

6 Target Architecture

6.1 General Concept of Operations

The IT architectures being presented herein are being developed in order to support the functional requirements and the concepts of operations laid out in several guiding documents from the JPDO, the FAA, and NOAA NWS. The guiding documents for the general concept of operations are listed in the reference document section with the primary documents listed below:

Document Name	Version	Date	Source
Concept of Operations for the Next Generation Air Transportation System	V2.0	6/13/2007	JPDO
NextGen Network-Enabled Weather IT CONOPS	3.2	8/20/2008	NCAR, MITLL, NOAA/GSD
Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management	0.1	1/18/2008	JPDO Functional Rqmts Study Team
Weather Concept of Operations	V1.0	5/13/2006	JPDO Weather Integrated Product Team
Concept of Operations and Operational Requirements - WIDB for the NextGen 07-042		5/4/2009	NWS Office of Climate, Water and Weather Services

The target architectures consist of proposed alternatives that NOAA NWS can implement to fulfill its obligation to develop the 4-D Weather Cube in support of JPDO and FAA NextGen weather requirements, as well as internal NOAA NWS requirements. The Cube itself is not being developed solely by NOAA NWS, rather it will be a federation of network-enabled services, some already existing, and some yet to be developed, and will be developed in close coordination with the FAA and the JPDO and its other members. The concept is that NOAA NWS will implement its side of the Cube to ingest and subsequently serve out weather information and data of interest to the aviation community using a distributed, net-centric architecture that will interact with the complementary systems architecture being developed by the FAA. Ingested data will come from a wide range of data providers within NOAA and NWS, as well as some external sources. The guiding concept behind the Cube is to provide a common access point for aviation users to access aviation weather information and data from multiple data providers and sources. The Cube will be implemented as a net-centric, distributed set of services. Operations of the Cube will also support the SAS, which will provide users with a single point for approved, authoritative aviation weather information. The concept of operations for the SAS is detailed in the reference documentation.

Key concepts and objectives to be supported by the target architectures include the following:

- Governance: Management of the information content in the Cube. This includes, but is not limited to, registration of data sources and products, management of standards and common ontologies, establishment of business rules for operations, and management of user authentication and authorization for various levels of access.

- Data Discovery: Implemented through the use of metadata and a federated registry/repository, this includes discovery of aviation weather data services, artifacts associated with services such as XML schemas, datasets, and access methods. Discovery will likely be partitioned into 'build-time' discovery, which generally refers to the discovery and downloading of service and message schemas, and 'run-time' discovery, which refers to the dynamic discovery of a dataset and/or service capable of accessing the dataset.

- Data Access: The target architectures are designed primarily to accommodate access to aviation weather data. This access will support push and pull delivery in the form of ad hoc requests from users and publish/subscribe operations. The Cube will be able to aggregate overlapping requests and will support geographical and temporal subsetting of data according to end users' needs.

- Decision Support: Operations of the Cube will support multiple automated and human-based decision support tools within the aviation user community.

- Verification / Quality Control: The Cube will incorporate several verification and quality control mechanisms. The primary verification service will be NEVS. Other verification services will include those employed by the NDFD as well as Stats On Demand (SOD). RTVS may be utilized for IOC in the event that NEVS is not fully operational with its planned replacement of RTVS functionality.

- Quality of Service: Through the managing governance services, the Cube, and in particular the SAS, will be capable of offering various levels of quality of service to end users. The target architectures are being developed to maintain a high level of availability including robust fault tolerance, load balancing across the network, and essential FAA support (99.9%) and critical FAA support (99.999%) availability.

- Agility: The target architectures for the Cube will support agile operations that will meet the requirements for a system that has the ability to easily add new source and destination systems, new data services and products, new data fields in existing products, and new users with little or no interruptions to ongoing operations. The Cube will support legacy systems as well as new systems and will be scalable over time.

- Security: Operations of the Cube will encompass stringent security including security of data, physical network security, and field by field and product by product access control.

- Monitoring: The target architectures incorporate the capability to monitor the network for hardware, software, network, and access anomalies and report these statistics back to the central management service.

The Cube will provide data services to a large community of aviation weather users from a variety of sources. Below is a listing of anticipated users:

- Air Traffic Managers
- Air Traffic Controllers (e.g., tower, TRACON, and en route)
- Flight Planners (e.g., dispatchers and general aviation pilots)

- Flight Briefers (e.g., flight service station controllers)
- Accident Investigators (e.g., NTSB, DoD, and FAA incident investigators)
- Dispatchers
- Airport Ground Crew (e.g., snow plow operators, de-icing technicians, and baggage handlers)
- Pilots, co-pilots or other Cockpit Crew Members including GA, commercial/professional
- Weather Data Providers (e.g., NOAA, NWS, NCDC, AFWA, FNMOC, NCAR, and MIT/LL)
- Community-of-Interest (COI) Members
- Scientists, Algorithm Developers
- Verification Systems (NEVS, NDFD, SOD, RTVS)
- Enterprise Service Managers
- Software Developers
- IT Maintenance Staff
- Forecast Generation Subsystems

6.2 Driving Architecture Assumptions

A number of key assumptions are driving NOAA's NextGen IT Architecture. These assumptions include the following which are detailed below.

- Use of a System of Systems approach
- Compatibility with key NOAA and NWS Enterprise Architecture guidance
- Compliance with NextGen requirements
- Supports IT ConOps Use Cases
- Compatible with FAA Architecture

6.2.1 System of Systems Approach

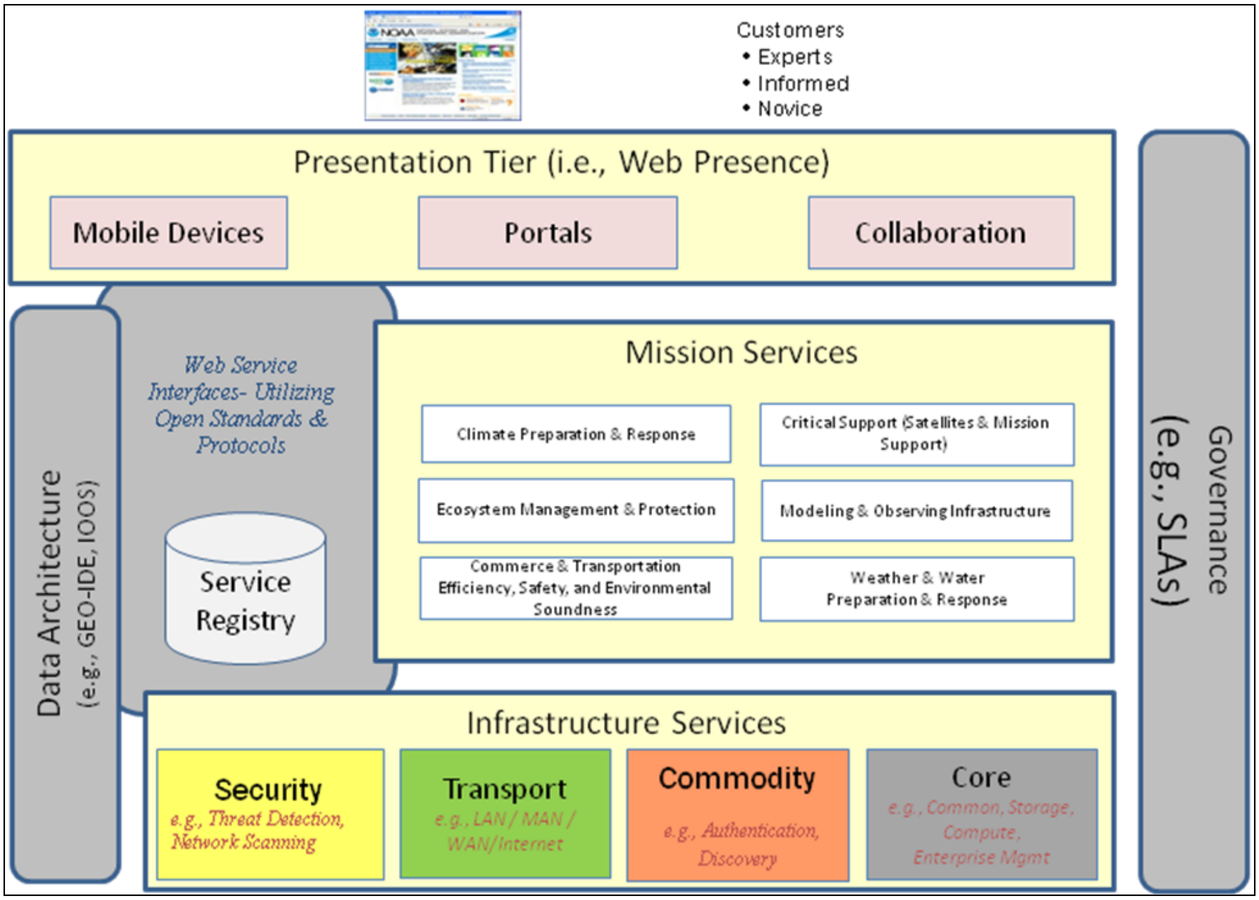
A System of Systems approach is being used to address the challenges associated within an environment defined by the interconnection of multiple systems across the large, multifunctional enterprises of FAA, NOAA, DoD, and amongst other aviation weather participants. Systems-of-Systems are defined by the independence of their respective components, their evolutionary nature, emergent behaviors, and a geographic extent that limits the direct interaction of their components to exchange information. Therefore, a System of Systems approach is not physical, it is instead a set of standards that allow meaningful communication among the components.

The NOAA IT architecture will follow this SOA-based system of systems design model in the implementation of its inter-enterprise application integration.

6.2.2 Enterprise Architecture Drivers

6.2.2.1 NOAA Enterprise Architecture (EA)

The NextGen IT Architecture will likely become a critical component of NOAA's future IT infrastructure. Many of the concepts being implemented to net-enable those NOAA systems required for aviation uses associated with the NextGen Cube will be adapted for other internal NOAA system-to-system information exchanges as well. Therefore, the proposed NextGen solution must be compatible with NOAA's own internal Enterprise Architecture approach. The NOAA EA provides a strategic representation of NOAA, defining its mission and business practices, and the information and technology necessary to perform its mission. The figure below presents a conceptual view of the Services and Data Layers associated with the EA.



The NextGen IT Architecture will be represented in a view that matches the intentions of the NOAA EA and its various lower level views.

6.2.2.2 NOAA Enterprise Architecture Technical Reference Model

Compatibility with the NOAA Enterprise Architecture also implies that the proposed IT Architecture solution must comply with NOAA's Enterprise Architecture Technical Reference Model (TRM). The TRM organizes and identifies IT standards, specifications, and products (i.e., collectivity defined as "technologies") that have been selected by NOAA's as vetted and approved. As presented in the TRM document, abiding by the guidelines established in the TRM is meant to:

- Enable and encourage reuse - allows NOAA to share services and technologies across organizational and functional lines
- Enhance interoperability – standardization enables greater interoperability across disparate applications, both internal and external
- Promote vendor independence - through the use of standards based products and interchangeable components

- Accelerate system implementation - provides an architecture from which components with well-defined functionality can be chosen to implement business functionality
- Simplify investment decisions - provides pre-approved components and pre-vetted architectural criteria to enhance NITRB and system review deliberations, as well as Line Office and program evaluation of alternatives
- Improve utilization of NOAA resources – reduces or eliminates duplicative investments and allows NOAA to better focus limited human resources (e.g., skillsets and training) on a rationalized, non-redundant and forward looking portfolio of enterprise IT standards.
- Improve NOAA's security posture – through explicit consideration of the security implications in the identification of all enterprise standard technologies

The TRM addresses NOAA-wide standardization in the following areas:

- Service access and delivery
- Service platform and infrastructure
- Component framework
- Service interface and integration

The NextGen IT Architecture will follow the guidelines proposed by the TRM.

6.2.2.3 NWS Enterprise Architecture

The NextGen IT Architecture will also follow the guidance established by the NWS Enterprise Architecture (EA) . The NWS EA is based on the NIST Enterprise Architecture Framework (NIST Special Publication 500-167) and the Federal Enterprise Architecture Framework (FEAF), and is consistent with the Department of Commerce (DOC) and NOAA EAs.

6.2.3 Requirements

The most important assumption associated with NOAA's NextGen IT architecture is that it complies with the requirements defined for it. NextGen is a bit different from many development projects since it is a cross-organization program, with many of its requirements defined only at a high level by various JPDO documents, with the expectation that the flow down of these high level requirements is accomplished by the individual system architects and developers. No central set of requirements for the IT architecture exist. This introduces a certain level of risk since it leaves these more detailed requirements to the interpretation of a diverse group. Therefore, interface requirements are the most important requirements to get agreement on early. Additionally, performance requirements are essential to ensure that the basic architecture can handle the potential wide variety of performance expectations.

To determine those requirements that drive the IT architecture, an extensive review of relevant NextGen documentation was performed. The documents that were reviewed are listed below:

Document Name	Version	Date	Source
Concept of Operations for the Next Generation Air Transportation System	V2.0	6/13/2007	JPDO

NextGen Network-Enabled Weather IT CONOPS	3.2	8/20/2008	NCAR, MITLL, NOAA/GSD
NextGen ATS Enterprise Architecture	V2.0	6/22/2007	JPDO
Four-Dimensional Weather Functional Requirements for NextGen Air Traffic Management	0.1	1/18/2008	JPDO Functional Rqmts Study Team
Weather Concept of Operations	V1.0	5/13/2006	JPDO Weather Integrated Product Team
NextGen Weather Plan	0.6	3/20/2009	JPDO
List of IOC and FOC products that NWS has committed to provide for NextGen			
Final Performance Requirements (iFR) First Working Draft Wrapper - 4-D Weather Data Cube SAS	Draft	2/11/2009	JDPO
NextGen Weather Information Database - Information Technology Needs (Draft SON)	Draft	3/13/2009	OST
Concept of Operations and Operational Requirements - WIDB for the NextGen 07-042		5/4/2009	Office of Climate, Water and Weather Services
Definition of 4-D SAS		6/17/2009	NEWP presentation by JPDO Wx Policy Team2
ATM Wx Integration Plan	Draft V0.7	4/22/2009	JPDO

These key documents contain an extensive amount of requirements and proposed NextGen functionality of which weather, and more specifically, IT architecture-based support for weather data exchange, is a small subset. From these requirements, additional requirements were derived, as necessary. These derived requirements address more detailed requirements in some cases, and implied requirements in other cases. Appendix A provides a list of those requirements that were determined to be relevant for the NextGen Weather Cube IT Architecture. The compiled requirement list was then categorized into the following requirement categories and sorted by these categories.

Requirement Categories
Access
Agility
Archival
Availability
Compatibility
Contents
Data consistency
Data formats
Data security
Data storage
Discoverability
Distributed
DST integration
General
Governance
Intelligent processing
IT
Logging
Netcentric
Network security
Performance
QOS
Request management
SAS determination
Schedule
Shared access
Subscription management
System Management
Users
Verification

A brief summary of some of the key requirements are denoted below:

- Access
  - Aggregate overlapping requests
  - High BW and low BW access methods support

- Agility
  - Ability to add new systems, services, products, data fields, users, etc. w/o system interruptions
  - Support legacy and new systems together
  - Scalable over time
- Archival / logging
  - Past transaction retrieval (e.g., for accident investigations)
- Availability
  - Fault tolerance
  - Load balancing
  - Essential FAA service support - .999
  - Critical FAA service support - .99999
  - SAS (essential):
    - MTTR - 0.5 hr,
    - MTBF – 5,000 hrs
    - Outage max – 10 mins
  - SAS (critical):
    - MTTR - 0.5 hr
    - MTBF – 50,000 hrs
    - Outage max – 6 secs
- Compatibility
  - With CWSUs, AWC, WFOs, Tower systems, TRACON systems, ARTCC, ATCSCC
- Contents
  - Support Wx Products required for aviation purposes, for example:
    - NOAA provided, FAA-provided, 3rd party provided
    - North American and global
    - Forecasts model data (probabilistic)
    - Sensor products
      - Radar, lightning, satellite, aircraft sensors, airport, ground, ocean, air, METARs
    - Observations – PIREPS
    - Advisories, watches, warnings
    - Climatological data
  - Formats
    - Grid based (machine readable) where possible
    - Encoded versions of legacy text products
    - Otherwise, text and graphical?
- Data Consistency
  - Deconflicted SAS (temporal and spatial)
- Data Formats
  - Allowing ease of exchange
  - Standards based
- Discoverability (metadata/registry/ repository)
  - Products/data
  - Formats
  - Access methods
  - Associated services
- Distributed (not centralized)
- Ease of decision support tool integration for aviation
- Governance
  - Access control
  - Standards
  - Common ontologies
  - Business rules
  - SAS
- Intelligent processing
  - Determining “weather hazards”

- Data interpolation
- Netcentric
  - SOA based
  - System of systems
  - Legacy system support (along with new systems)
- QOS / Performance
  - Varies by user / use case / function
- Request management
  - Request / reply exchange mechanisms
  - Data for time period of choice
  - Data for geographical construct of choice
  - Product / data field of choice
  - Priority
  - Desired format / translations
  - Compression
- Security
  - Data security
  - Physical / network security
  - Field by field, product by product access control
- Subscription management support
- SAS management and governance
- System management
  - Failure detection / switchover
  - Load balancing
  - Health monitoring / analysis / trending / logging
- Users supported
  - Aviation (primarily), governmental, commercial, military, international
  - Non-aviation, research, NOAA-internal
- Verification / quality control

6.2.4 IT Conops Use Cases

A seminal document in the NextGen project is NextGen Network-Enabled Weather IT Conops. Absent a specific comprehensive document that addresses the requirements associated with the NextGen IT architecture, the IT Conops document provides a number of illustrative use cases addressing how the Cube might be used. In doing so, it:

- Provides a user-friendly way for end users to describe the requirements to the Cube designers
- Captures sufficient detail for architects of the various systems involved in the Cube to design their respective systems
- Provides information necessary for testing and requirements traceability

Given the large number of current and potential future weather providers and consumers, the use cases presented were not intended to be exhaustive or to highlight all possible actors. The focus instead was on providing a minimal but comprehensive set of use cases that effectively 'spans the problem domain,' allowing system architects to work with a manageable amount of information during the 4-D Wx Data Cube design phase. It is anticipated that new use cases will be incorporated as needed to maintain good problem domain coverage.

The currently defined use cases address the following areas:

- Information management
  - Governance
  - Discovery

  - Data access
- Agility
- Quality of service
- Fault tolerance
- Security
- Monitoring
- Cost minimization

Due to the critical nature of the IT Conops document, it is instrumental in developing many IT architecture requirements and will serve as an important resource in ensuring the proposed IT architecture supports the use cases contain within. It is important to recognize that the use cases are continuing to evolve as the NextGen program progresses and as they evolve, so too must the IT architecture.

6.2.5 FAA Architecture Compatibility

Compatibility with the FAA portion of the Cube is essential to ensure an efficient and effective NOAA IT architecture implementation. To this end, extensive efforts have been undertaken to better understand the FAA intended architecture and to work closely with FAA architects as that architecture evolves. This section presents a summary description of the FAA Cube architecture as it is currently envisioned. It too is evolving so continued close coordination will be required to ensure the NOAA and FAA Cube architectures remain compatible.

6.2.5.1 Overview

6.2.5.1.1 Sources

Numerous FAA-provided resources were used in documenting the FAA architecture description below, including.

- NextGen Network Enabled Weather Program 4-D Weather Cube White Paper
- 4-Dimensional Weather Data Cube Web Feature Service Reference Implementation (WFSRI) Requirements
- 4-Dimensional Weather Data Cube Web Coverage Service Reference Implementation (WCSRI) Requirements
- 4-Dimensional Weather Data Cube Web Feature Service Reference Implementation (WFSRI) Architecture and Design
- 4-Dimensional Weather Data Cube Web Coverage Service Reference Implementation (WCSRI) Architecture and Design
- NextGen Weather Data Flow and 4-D Weather Data Cube Service Adaptor Plan document
- FAA-developed IOC Product Flows worksheet
- NextGen Network-Enabled Weather Metadata Guidelines for the 4-D Weather Data Cube

6.2.5.1.2 Hub/Spoke – Store/Forward Approach

The FAA-portion of the Cube will employ a hub and spoke model of data distribution to efficiently disseminate its data to customers. The concept behind a hub and spoke model is to reduce the number of point-to-point connections while centralizing data concerns close to the source.

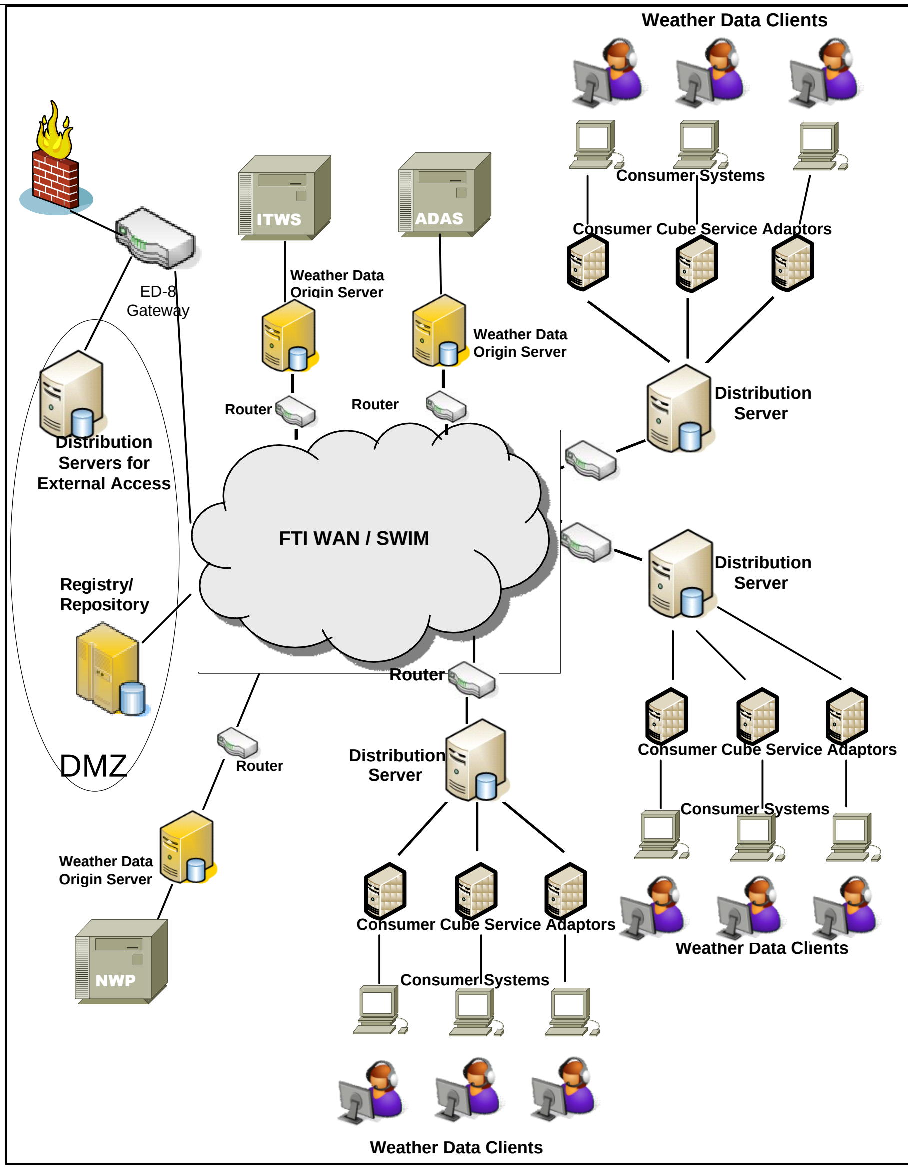
The hub and spoke model will be combined with a *store and forward* data distribution technique. Store and forward uses an intermediary data cache (via Distribution Servers) as a primary means of data delivery for distant consumers. This increases the response time from the original data provider to the consumer system in some cases, but also distributes load more efficiently throughout the system. It also increases availability of data by replicating the original provider data to the spokes within the hub and spoke model, allowing for better performance, scalability, and cost-efficiency.

The framework for implementing the FAA content-delivery network will be employed through the deployment of highly agile, scalable, and configurable Origin Server and Distribution Servers nodes.

The weather data provider feeds data to the Origin server. The Origin Server ingests data from the provider, transforms that data, and inserts it into a local data store.

Via their local Consumer System, a Weather Data Client requests or creates a subscription to data that are produced by the distant weather data provider using a Consumer Cube Service Adaptor (CCSA). The CCSA formats and forwards the request to a Distribution Server. The request is handled by a local Distribution Server (Spoke). If the Distribution Server does not have the requested data locally, it makes a request to the Origin Server (Hub) via network of Distribution Servers. Once the data are retrieved, Distribution Servers will locally cache the data from the Origin Server in anticipation of additional requests. Furthermore, as a configurable option, the data will automatically begin to replicate and refresh to the Distribution Server from the Origin Server as new data updates become available.

The figure below depicts the key components of the FAA Wx Cube architecture and the sections that follow address these key components.



6.2.5.2 Baseline Communication Infrastructure

6.2.5.2.1 SWIM

SWIM is an FAA enterprise IT infrastructure program that is implementing a system which will apply the SOA paradigm to NAS applications by utilizing state-of-the-art, net-centric, information management and exchange technologies. SWIM will accomplish its goals by providing IT infrastructure capabilities to the NAS enterprise in the form of Core Services and enterprise governance. Core Services enable “business services” to be available throughout the enterprise while maintaining loose-coupling and maximizing reuse and consistent implementation. These core services will include

> **Interface Management** includes interface specification and interface discovery as well as support for managing the schemas that define data format and semantics for interface data

elements. Interface Management also covers the runtime capability provided by Service Invocation which covers the connectivity and communication aspects of core services.

Messaging covers how data are passed between applications. It includes how the data envelope is structured (SOAP) and how metadata supports content based routing and policy. It also covers reliable delivery.

Security covers how both service consumers and providers authenticate themselves, assert privileges, and provide confidentiality for invoking and consuming services at both the application endpoint and security levels.

Enterprise Service Management has two aspects. The first is how services are governed. This includes managing the development, deployment, operation, and retirement phases of a service. Services are managed based on the required Quality of Service (QoS) as expressed by a Service Level Agreements (SLA) between the service provider and potentially many service consumers. Second, monitoring covers how SWIM oversees the operational system to ensure that SLAs are being met.

More details about the FAA's SWIM technology can be found in the NextGen Network Enabled Weather Program 4-D Weather Cube White Paper, as well as other FAA documentation.

6.2.5.2.2 FAA Telecommunications Infrastructure (FTI)

The FTI is the physical telecommunications network that interconnects FAA facilities nationwide. It is used to carry mission and operationally critical data for air transportation needs throughout the NAS.

The FAA-portion of the Cube will use the FTI Operational IP network as the underlying backbone of data transport within the FAA.

In order to facilitate access without creating a direct connection, boundary protection functions such as Service Delivery Points, Internet Access Points, and Dedicated Telecom Services will be used to allow seamless access to FAA-portion of the Cube data from outside of the NAS while conforming to FAA security policies.

More details about FTI can be found in the NextGen Network Enabled Weather Program 4-D Weather Cube White Paper, as well as other FAA documentation.

6.2.5.2.3 External Access

Since FAA security policies preclude any direct connection of non-NAS systems to NAS systems, security extranet gateways will utilize boundary protection mechanisms (including DMZs, firewalls, and data filtering devices) to allow non-NAS systems to access Cube data residing in the NAS and vice versa. These extranet gateways are referred to as "ED-8" gateways by FTI.

6.2.5.3 WCS/WFS Reference Implementation (RI)

An RI is software that provides a definitive interpretation and implementation of a standard. RIs are intended to be highly configurable pieces of software. Several RIs are being developed for use within the FAA-portion of the Cube that will be based on the Web Coverage Service (WCS) and Web Feature Service (WFS) Open Geospatial Consortium (OGC) standards. They are being designed to accommodate different data models and formats and are intended to be the functional software component that allows the Cube's data to be available. Separate Requirements documents and Architecture and Design documents are available to address the WCS RI and WFC RI respectively. These RIs are also being made available to non-FAA entities for use in their own Cube implementations.

6.2.5.3.1 WCS – For Gridded Data

The OGC defines many widely adopted standards related to geospatial data interchange and definition, including Geography Markup Language, Web Feature Service, Web Map Service, etc. The consortium consists of over 370 members, including governmental agencies, private companies, and educational institutions. Ref: http://www.opengeospatial.org/standards

WCS, developed by the OGC, specifies a standard access protocol for coverage data. A **coverage** is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type. Because coverages can be roughly defined as any type of data that includes a number of attributes relevant to a particular geographic location, this includes any conditions that are universally applied to a geographic area. For example, a surface observation that includes measurements of air temperature, humidity, and cloud ceiling may be considered a coverage.

WCS supports the networked interchange of geospatial data as "coverages" containing values or properties of geographic locations. The Web Coverage Service provides access to intact (unrendered) geospatial information, as needed for client-side rendering, multi-valued coverages, and input into scientific models and other clients beyond simple viewers. The Web Coverage Service consists of three operations: GetCapabilities, GetCoverage, and DescribeCoverageType. The GetCapabilities operation returns an XML document describing the service and the data collections from which clients may request coverages. Clients would generally run the GetCapabilities operation and cache its result for use throughout a session, or reuse it for multiple sessions. The GetCoverage operation of a Web Coverage Service is normally run after GetCapabilities has determined what queries are allowed and what data are available. The GetCoverage operation returns values or properties of geographic locations, bundled in a well-known coverage format.

WCS specification has been chosen by the FAA architecture team as the NNEW Program's weather data dissemination standard for gridded data for a variety of reasons. Firstly, the WCS specification is built upon several other open and broadly used standards (e.g., ISO 19135, ISO 19123, ISO 19115 and other OGC standards). Also, a standards foundation is required for widespread interoperability and adoption, and reflects the maturity of this specification. In addition, a WCS specification includes a wide community of organizations in the standards definition process and promotes a general solution that likely satisfies the interests of the majority of stakeholders while minimizing the influence of individual intentions. As a result, the artifacts produced by the OGC are generally and widely applicable.

The WCS specification has broad geospatial applicability beyond the weather domain. This allows other disciplines—such as aeronautical, environmental, and air traffic information—to share data and access protocols through geospatial constructs rather than through domain-specific (e.g., weather-specific) constructs.

Other aviation programs within the FAA and internationally have shown interest in adopting OGC-related standards, which would enhance interoperability. The presence of aviation and weather organizations on OGC committees increases the likelihood that relevant stakeholder's needs are met. As the specification stands now (Revision 1.1.2), most of the gridded data access requirements defined in the IT CONOPS Use Cases (e.g., subsetting) have been satisfied. For needs left unmet, NNEW and other participating organizations influence the standards definitions process by taking part in OGC committees and working groups. Lastly, in most cases the generality and flexibility of the specification allows for extensions to be defined meeting additional needs.

Gridded coverage data can physically be stored in many file formats, and can also be exposed via the external interface in many formats. NetCDF 4 is an efficient, flexible file format that has been widely adopted by the scientific community, especially for weather data. It is supported by a wide variety of libraries (i.e., application programming interfaces (API)) which makes the file format easier to use. The format also supports compression which is an important consideration for minimizing disk space and bandwidth usage. Since data of any shape and projection can be represented as NetCDF, conventions are typically adopted to impose well-known structure to a particular file. The FAA WCSRI will be standardized to support NetCDF4 as its primary file format for the exchange of gridded data. The GRIB2 data format is also widely used by current and legacy weather applications. Because GRIB2 plays a significant role in the weather community, it may also be adopted as a standard within the 4-D Wx Data Cube. As a result, GRIB2 is a potential requirement for the WCSRI. Consideration is also being given to the support of other common gridded file native formats. At a minimum, the FAA architecture will support the ingest and storage of these non-NetCDF formats; however, all WCSRI processing (spatial and temporal filtering, etc.) and resultant file exchange between FAA system components will be done using the NetCDF4 format.

6.2.5.3.2 WFS – For Non-Gridded Data

The OGC Web Feature Service (WFS) allows a client to retrieve geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services. Features are an abstraction of a real world phenomenon. A geographic **feature** is a feature associated with a location relative to the Earth. A digital representation of the real world can be thought of as a set of features.

The general requirements for a Web Feature Service are:

1. The interfaces must be defined in XML.
2. GML must be used to express features within the interface.
3. At a minimum a WFS must be able to present features using GML.
4. The predicate or filter language will be defined in XML and be derived from CQL as defined in the OpenGIS Catalogue Interface Implementation Specification.

5. The datastore used to store geographic features should be opaque to client applications and their only view of the data should be through the WFS interface.
6. The use of a subset of XPath expressions for referencing properties.

WFS specification has been chosen by the FAA architecture team as the standard for the NNEW Program's weather data dissemination of non-gridded data for a variety of reasons. The WFS specification is built upon other open and broadly used standards, for example ISO 19105. The inclusion of a wide community of organizations in the standards definition process promotes a general solution that likely satisfies the interests of the majority of stakeholders while minimizing the influence of individual intentions. As a result, the standards produced by the OGC are generally and widely applicable. The WFS, developed by the OGC, specifies a standard access protocol for feature data.

The WFS specification has broad geospatial applicability beyond the weather domain. This allows other disciplines -- such as aeronautical, environmental, and air traffic information -- to share data and access protocols through geospatial constructs rather than through domain-specific (e.g., weather-specific) constructs. Other aviation programs within the FAA and internationally have shown interest in adopting OGC-related standards. The presence of aviation and weather organizations on OGC committees increases the likelihood that their needs are met. NNEW and other participating organizations are able to influence the standards definitions process by participating in OGC committees and working groups. In most cases the generality and flexibility of the specification allows for extensions to be defined to meet additional needs.

The WFSRI is currently being developed to support the joint Eurocontrol/FAA Weather Information Exchange Model (WXXM 1.1) encodings of XML as the input and output format for non-gridded data within the FAA-portion of the Cube.

6.2.5.3.3 Message Exchange Patterns (MEPs)
The FAA RIs (OGC Web Features Service and Web Coverage Service) currently support a request/response message exchange pattern (MEP) based on an HTTP-based transport. The FAA RI efforts include extending the WFS and WCS standards to include support for a publish/subscribe MEP, using the SWIM-supplied JMS message broker as the transport layer.

6.2.5.4 Data Provider Systems

6.2.5.4.1 Provider Systems
The weather data provider is a weather system/application that feeds data to an FAA Origin Server. The Origin Server ingests data from the provider, transforms that data, and inserts it into a local data store.

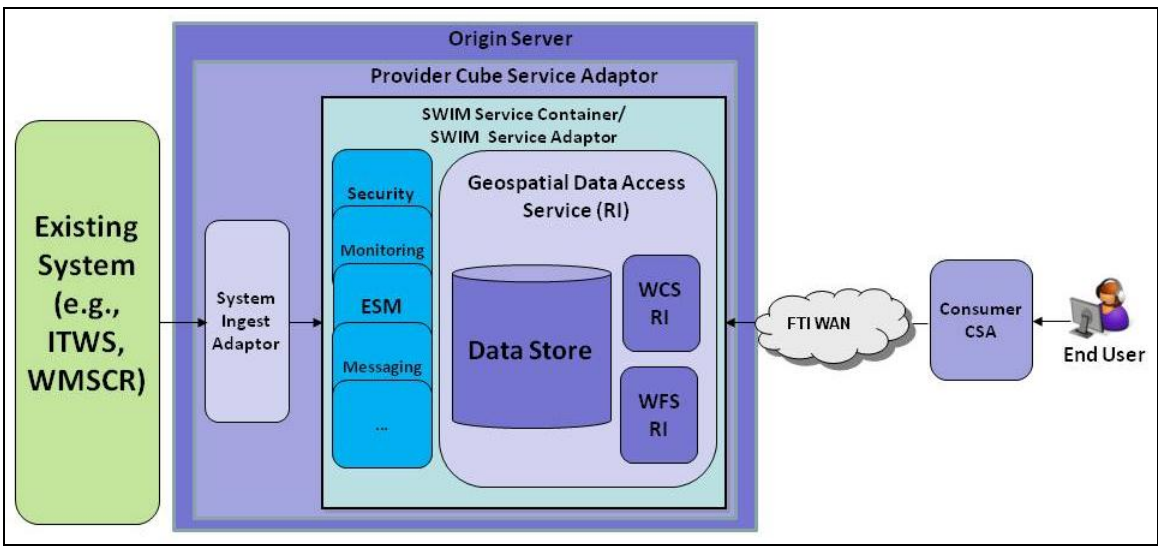
The NextGen Weather Data Flow and 4-D Weather Data Cube Service Adaptor Plan document, along with FAA-developed IOC Product Flows worksheet addresses those systems that are under consideration as Provider Systems, along with the intended destination systems for the weather data.

6.2.5.4.2 Origin Servers (OS)

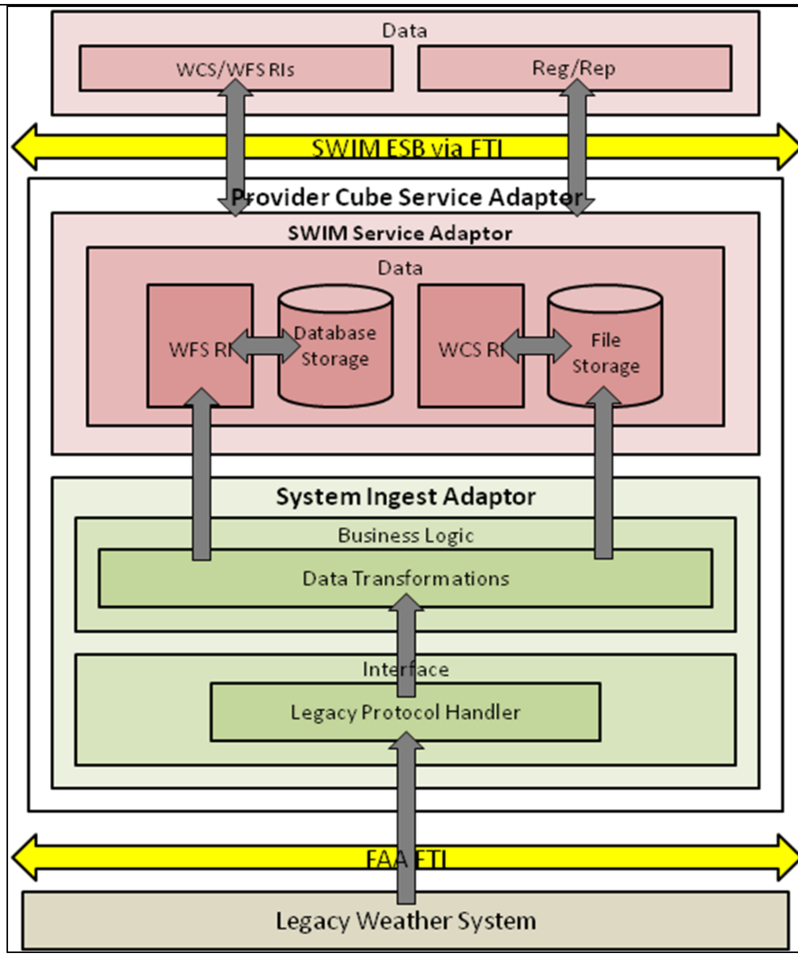
An Origin Server ingests data from a FAA weather data provider system, transforms that data, and inserts it into a local data store. The Origin Server will be as close as possible to the physical location of the data provider to ensure efficiency. There is a 1-to-1 relationship between data provider systems and Origin Server instances. The Origin Server is comprised of a number of different components, but its fundamental purpose is to serve as a Provider Cube Service Adaptor (PCSA) for data providers. The term *Service Adaptor* is a commonly used SOA term and is also used within the SWIM program to describe the primary means of systems connecting their NAS applications to SWIM. The FAA-portion of the Cube will use the SWIM Service Adaptor as the foundation. The PCSA is a modified SWIM Service Adaptor that has been enhanced with software that implements weather domain specific standards.

The PCSA contains the System Ingest Adaptor and the SWIM Service Adaptor; the SWIM Service Adaptor is in the form of the SWIM Service Container and a Geospatial Data Access Service. The SWIM Service Container also provides SWIM core services. The Geospatial Data Access Service is broken down into a data store and reference implementations (RI) that provide the service interface.

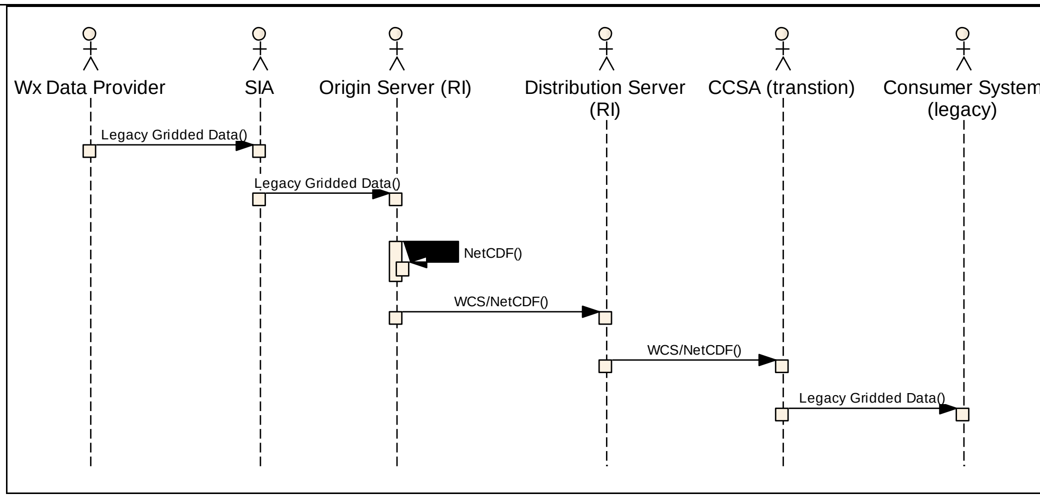
The figure below depicts the functional components of an Origin Server.



A System Ingest Adaptor will ingest NAS weather application data and perform any transformations necessary before inserting it into a data store. The data store is accessed by the RIs. The System Ingest Adaptor will either be notified by the data provider system that fresh data is available for ingest, or will periodically poll the data provider system to determine if fresh data is available. As the figure below shows, the System Ingest Adaptor consists of an interface component that serves as a Legacy Protocol Handler and a business logic component that performs the Data Transformations and provides the resulting transformed data into the appropriate Origin Server data stores. The SIA will use the WFS-Transaction (Insert) operation to write feature data into the database. The method the SIA will use to update the data store with coverage data is still under consideration.



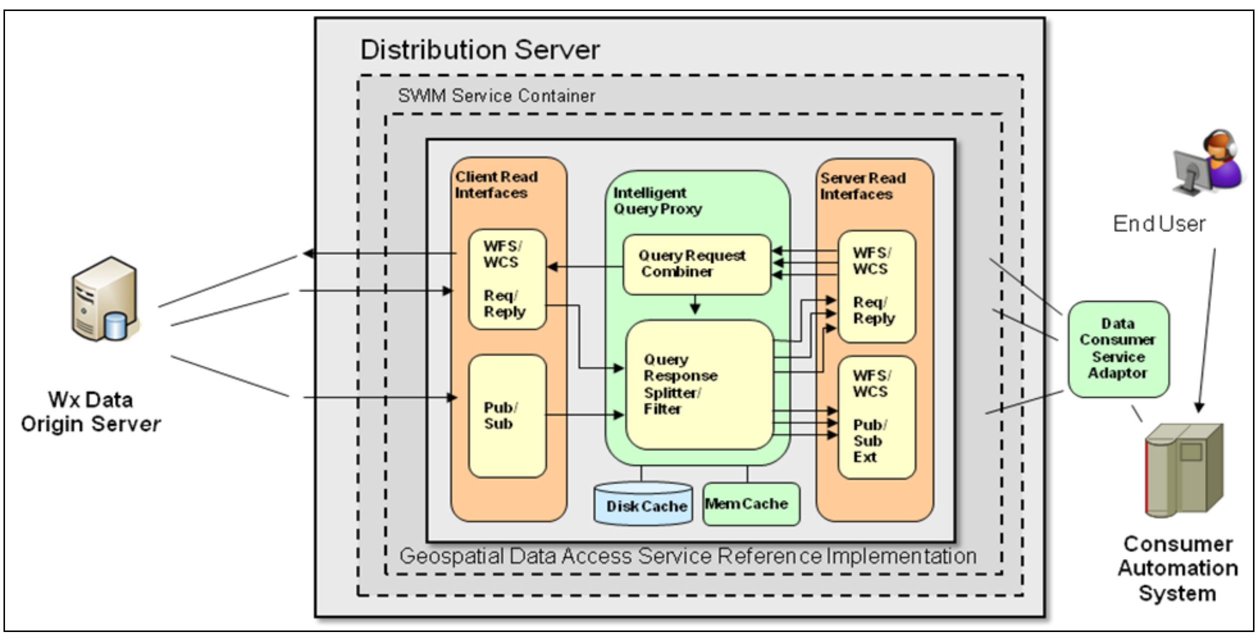
Non-gridded data is transformed by the System Ingest Adaptor and stored in a database in WXXM format for eventual generation of WXXM formatted responses via the WFS RI. Gridded data will be ingested and stored in its native format (NetCDF4-format is preferred, although GRIB2 and possibly other formats may be supported). Any non-NetCDF4 formats would then be transformed by the WCS RI to NetCDF4 format and all subsequent WCS RI processing (spatial and temporal filtering, etc.) and the resultant file exchange between the Origin Server and requesting FAA Distribution Servers will be done using the NetCDF4 format as depicted below.



6.2.5.5 Data Users / Destinations

6.2.5.5.1 Distribution Servers (DS)

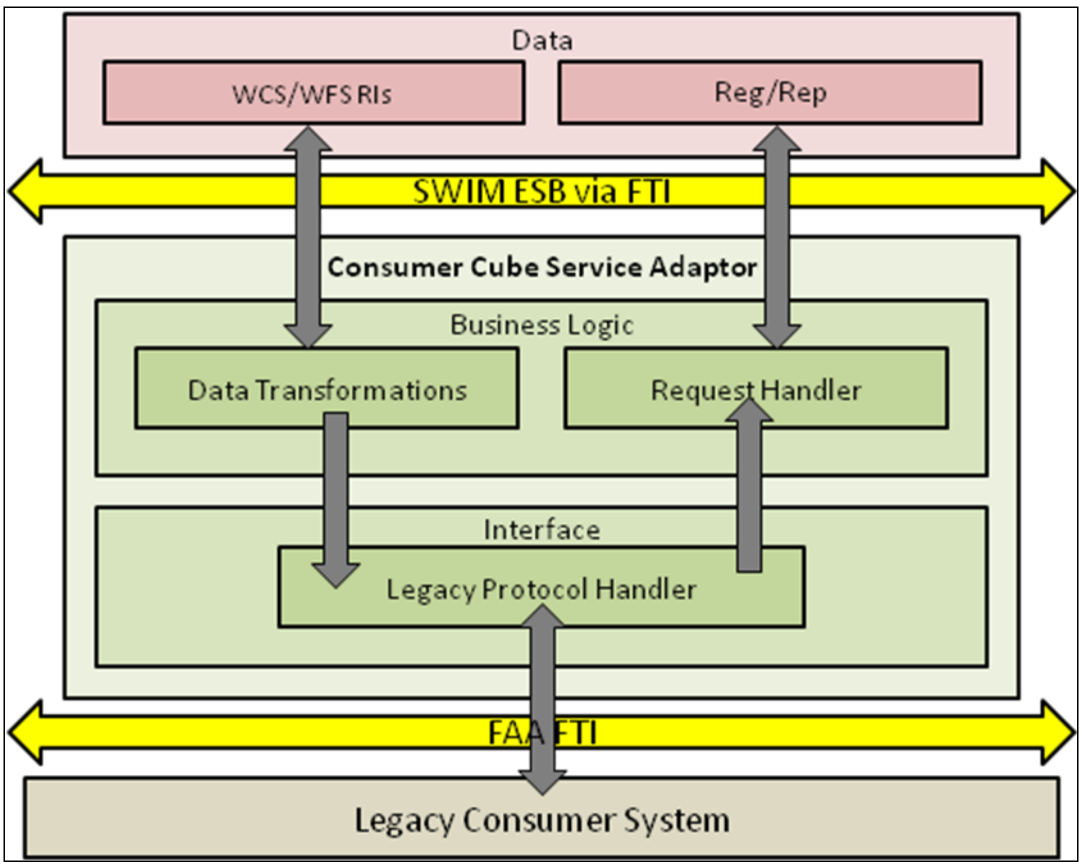
Distribution Servers will also have a many-to-one relationship with Origin Servers where many Origin Servers can feed a single Distribution Server with data as updates become available. Each Distribution Server has a WCS and WFS interface and respective RIs (i.e., Client Read Interfaces) to allow it to communicate to a corresponding WCS/WFS server running on an Origin Server, as well as has a WCS and WFS interface and respective RIs (i.e., Server Read Interfaces) to allow it to accept data requests from Consumer Systems via a Cube Consumer Service Adaptor (CCSA). The Distribution Server also contains an Intelligent Query Proxy that ascertains whether requested data is resident in local cache, or must be retrieved from an upstream Distribution Server or the originating Origin Server. The figure below provides a notional depiction of the Distribution Server.



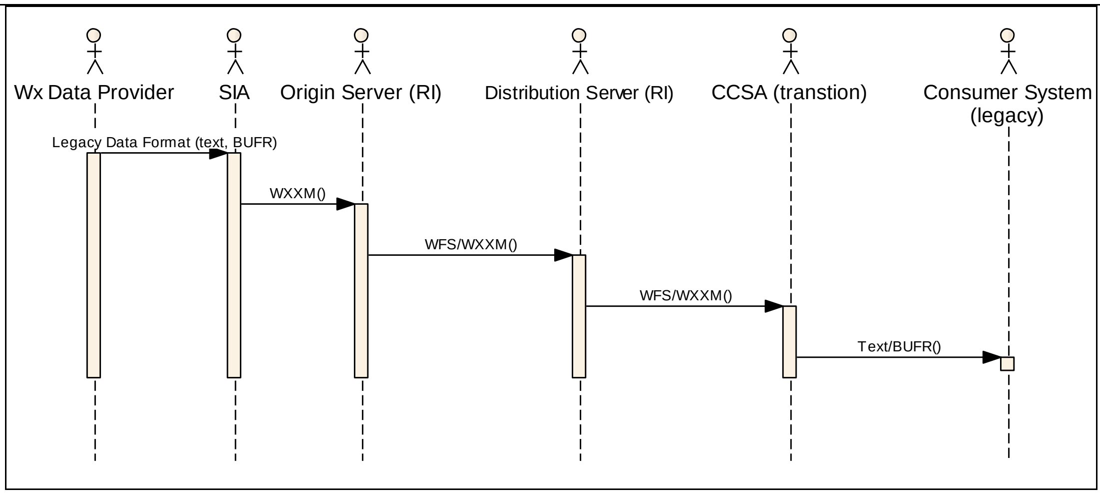
Similar to the Origin Server, the Distribution Server is in the form of the SWIM Service Container and a Geospatial Data Access Service. The SWIM Service Container provides SWIM core services. The Geospatial Data Access Service is broken down into the caching functions, WCS/WFS reference implementations (RI) that provide the service interface, and internal processing. The Distribution Server can request metadata from the Reg/Rep before contacting the desired Origin Server via a SOAP interface to the Reg/Rep.

6.2.5.5.2 Consumer Cube Service Adaptors (CCSA)

The Consumer Cube Service Adaptor (CCSA) is the mechanism that allows for Consumer Systems to request weather data from the Cube, and then to convert that data into a useable format. The CCSA may be a separate and distinct system that interfaces a Consumer System to the Cube, or it might be embedded into a Consumer System. The CCSA has a Cube-facing WFS/WCS client interface to allow it to communicate with a Distribution Server. As the figure below shows, the CCSA contains Data Transformation and Legacy Protocol Handler functions to convert data received from the Cube into a format directly usable by the requesting Consumer System and to deliver that data to the requesting Consumer System.



This may include converting gridded data from NetCDF4 format into the desired native gridded format (e.g., GRIB2) or converting WXXM formatted data into a legacy format (e.g. Text or BUFR) as the figure below depicts.



The CCSA also contains a Request Handler function. The Request Handler responds to requests by the Consumer System. These requests are envisioned to be in the form of an exchange of parameters that define the requested product, format, Message Exchange Protocol (MEP) type (e.g., subscription or request), time range (e.g., real-time or past data), as well as spatial region of interest.

6.2.5.5.3 Consumer Systems

Consumer Systems may include anything from NAS automation systems to web-based user interfaces to allow access to distant weather source data by Data Clients. The NextGen Weather Data Flow and 4-D Weather Data Cube Service Adaptor Plan document, along with FAA-developed IOC Product Flows worksheet addresses those systems that are under consideration as Consumer Systems, or destinations, of weather data, along with the intended source systems for the weather data.

6.2.5.5.4 Wx Data Client

The Weather Data Clients are the end users of the weather data. They access Cube weather data via a Consumer System.

6.2.5.6 Registry/Repository

The Cube's infrastructure also includes an ebXML Data Management Registry/Repository (data management registry). The data management registry will store metadata about the datasets of the Cube, segregate those datasets into domains, and provide a semantically enhanced, data-discovery mechanism.

The data management registry of the Cube will be used as a semantically enhanced, dataset-discovery mechanism. This will occur through the use of an ontology which is being developed for the Cube. The ontology will allow, for example, a NOAA user to use a NOAA-specific term for a weather parameter and be returned a list of results that includes not only NOAA datasets, but relevant FAA and/or DOD datasets as well.

The Reg/Rep will support a Web-based management / administrative / user interface. The Reg/Rep also supports a SOAP and REST based machine-to-machine interface.

In addition, the data management registry will also be utilized as a runtime registry to search for and dynamically request and subscribe to Cube data. A runtime environment will provide the Cube with system agility, which is a Cube requirement for SAS functions. Putting the dataset and service address information in a registry and allowing it to be discovered at runtime allows that information to be subject to centralized governance. This makes it quite straightforward to change the address of a service should the need arise (fault-tolerant scenarios, end-of-life scenarios, etc.). However, it is not envisioned that the Registry would be used to indicate whenever weather information has been updated / refreshed (e.g., the most recent on-the-hour forecast model run is now available or an updated observation/measurement is now available).

The concept of the SAS for a given weather product is central to the Cube concept and requires that datasets are classified as being in the SAS domain or not. Datasets that comprise the SAS will periodically change, and may ultimately be automatically changed in real time based on algorithms that will evaluate the relative "goodness" of various datasets. In view of this, runtime discovery is a requirement of the Cube.

6.2.5.7 Metadata Standardization

Metadata are a key enabler for many of the capabilities envisioned for the 4-D Weather Data Cube. Metadata standards and best practices are still evolving relatively rapidly. The *NextGen Network-Enabled Weather Metadata Guidelines for the 4-D Weather Data Cube* document provides a set of metadata guidelines developed by the FAA NNEW Program, based on prototyping performed to date. The focus of this initial version of the document is on metadata standards and practices that enable flexible discovery and access to all types of weather datasets. Some initial guidelines are also provided in support of sensor description metadata using the SensorML standard. Future work will include guidelines for metadata associated with fine and coarse-grained security, as well as Quality of Service (QoS). The following table summarizes the key metadata-related standards discussed in the current Metadata Guidelines document.

Standard Name	**Description**
ISO 19115	General metadata standards for datasets of all types. This is an abstract specification, describing the data model in Unified Modeling Language (UML).
ISO 19119	Extended Service metadata. This is an abstract specification, describing the data model in UML.
ISO 19139	Standard XML schema for the abstract ISO 19115/19119 metadata models
Web Services Description Language (WSDL)	Basic service metadata, including the abstract service interface as well as instance endpoint information.
NetCDF-4 CF	Earth science community data format with

	associated metadata
ebXML Registry Information Model (ebRIM)	Generalized information model for ebXML registry/repository.
SensorML	Standard metadata for describing sensors and their capabilities
ISO 8601	Standard for representation of time. Time is a common element used by many of the above standards.
RFC 4198	Uniform Resource Name (URN) namespace for federated content

6.2.5.8 NOAA Related Implications of the FAA Architecture

To support access to FAA weather data by requesting external (non-FAA) entities, the requesting entity (e.g., a NOAA Cube Output Edge Services (COES)) may be allowed direct access to an FAA Origin Server (via a WCS or WFS request). However, in the more likely architecture approach, the requesting entity will access that desired data via a WCS/WFS query to an FAA-supported Outbound Distribution Server (possibly physically located at the ED-8 Gateway or in a network DMZ). The Outbound Distribution Server would be responsible for obtaining the desired data from the appropriate FAA Origin Server and returning it to the requesting external entity or routing the request to the appropriate FAA source.

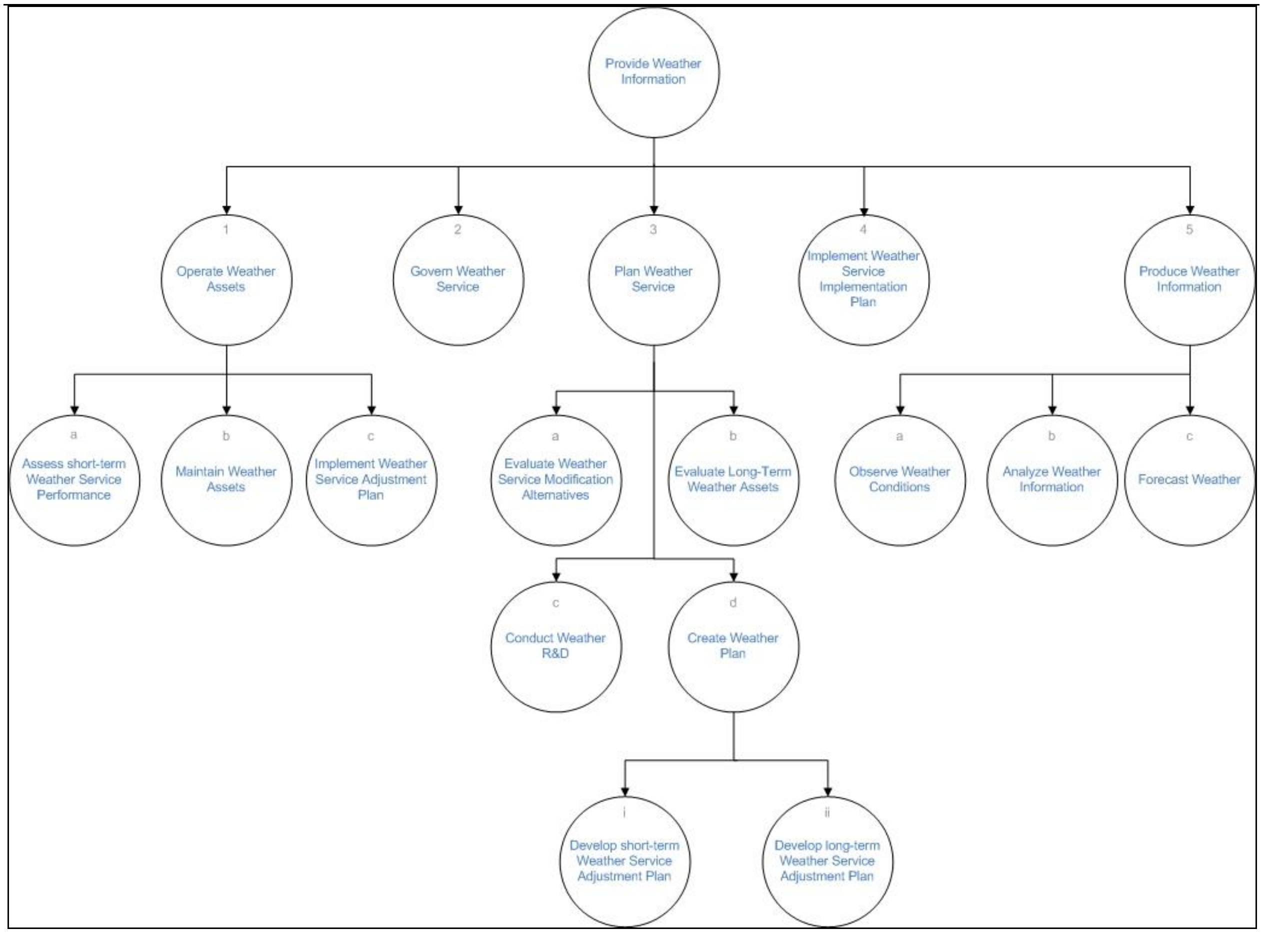
Similarly, for FAA Consumer System access to non-FAA weather data, this may be accomplished by allowing each CCSA to access the external entity's source server (e.g. a NOAA Cube Input Edge Services (CIES)) directly. However, in the most likely approach, an FAA-supported Inbound Distribution Server will be implemented (possibly physically located at the ED-8 Gateway or in a network DMZ) to serve as an intermediate request aggregation node, offloading direct access to CIESs. The Inbound Distribution Server would be responsible for obtaining the desired data from the appropriate external entity's source server and returning it to the requesting CCSA.

6.3 Business Process Model

The Business Process Model for NextGen is represented by its Business Services, their inter-relationships, and the respective information flows amongst these Business Services. This section presents the NextGen Business Process model by building on the work done by the JPDO in their extensive Enterprise Architecture definition efforts.

6.3.1 Business Services

High-level Business Services supported by NextGen are in the process of being captured and refined as Operational Activities (OAs) in the JPDO NextGen Enterprise Architecture (FY11). Key Wx-related Operational Activities are provided in Enterprise Architecture artifact OV-5 – Activity Model. The figure below is from this Activity Model artifact. Specifically, it depicts the breakdown of the *Provide Weather Information* NextGen operational activity presented in the Activity Model into lower level activities, from which the genesis or need for the NextGen Wx Cube is obtained. Therefore, the ultimate purpose of the 4-D Weather Cube and its corresponding requirements can be derived from these sets of business services / operational activities.



The *Provide Weather Information* operational activity and its comprising lower level operational activities depicted in the figure above are further detailed below. These sections are directly from the JPDO NextGen Enterprise Architecture (EA) documentation and are presented in this document to provide an overview of the key weather activities associated with NextGen; the reader should refer to the JPDO NextGen EA documentation if more details are desired. Where appropriate in the discussion of the weather activities below, key areas that directly relate to the needs of and features that must be support by the 4D Weather Cube are highlighted.

6.3.1.1 Provide Weather Information

The *Provide Weather Information* activity supplies weather information to NAS users by ensuring the assets, people, procedures and policies that produce the information are in place. The activity begins with the receipt of user needs and market information to guide the planning for and acquisition of weather assets. Private weather information, time, and position are used to produce weather information while adhering to applicable policies, standards, and agreements. The *Provide Weather Information* activity is comprised of the following component activities:

- *Operate Weather Assets*
- *Govern Weather Service*

- *Plan Weather Service*
- *Implement Weather Improvement Plan*
- *Produce Weather Information*

Inputs to and outputs from the *Provide Weather Information* activity are as follows:

- **INPUTS:** Market Information, User Needs (Weather), ICAO Standard, Industry Standard, Space Conditions, Atmospheric Conditions, Surface Conditions, Private Weather Information
- **OUTPUTS:** Weather Forecast, Weather Information, Design Documentation (Weather)

6.3.1.1.1 Operate Weather Assets

The *Operate Weather Assets* activity performs the day to day management, maintenance, and administration necessary to keep weather assets (i.e. tools, personnel, and facilities) in such a condition that they will perform as required per design documentation. This activity also implements short-term adjustments to the weather service in accordance with the standards laid by an adjustment plan. These changes use weather tools, facilities and operations personnel and may include, but are not limited to, redeployment of existing weather assets and/or adjustment of operational controls. The *Operate Weather Assets* activity is comprised of the following component activities:

- *Assess Short-Term Weather Service Performance*
- *Maintain Weather Assets*
- *Implement Weather Service Adjustment Plan.*

Inputs to and outputs from the *Operate Weather Assets* activity are as follows:

- **INPUTS:** User Needs (Weather)
- **OUTPUTS:** Performance Report (Weather), Change Request (Weather)

6.3.1.1.1.1 Assess Short-Term Weather Service Performance

The *Assess Short-Term Weather Service Performance* activity reviews the daily operation of the weather assets to measure weather asset performance against defined metrics. It begins with the assessment of user needs and weather asset performance against the design documentation and produces a performance report. Any deficiencies in performance are reviewed against maintenance reports to determine the state of the issue (i.e. a known issue). If a performance gap is identified, this activity generates a corresponding selected adjustment plan, change request, or maintenance request to address the gap. A selected adjustment plan results if the identified issue can be addressed by a previously developed adjustment plan; a change request is made if it is determined a change in the configuration can address the gap; a maintenance request is made if maintenance to a current asset can address the gap. This activity is conducted using performance monitoring tools, operations personnel, weather tools, weather facilities and reconfigured weather assets.

Inputs to and outputs from the *Assess Short-Term Weather Service Performance* activity are as follows:

- **INPUTS:** User Needs (Weather), Maintenance Report (Weather)
- **OUTPUTS:** Performance Report (Weather), Change Request (Weather), Maintenance Request (Weather), Adjustment Plan Selection (Weather)

6.3.1.1.1.2 Maintain Weather Assets

The ***Maintain Weather Assets*** activity performs the routine processes, procedures, servicing, replacement, repair, and training necessary to keep weather assets (i.e. tools, personnel, and facilities) in such a condition that they will perform as required per design documentation. This activity begins with the receipt of a maintenance request and references design documentation, operational procedures, and available funding for appropriate action. This activity uses facilities, tools, and personnel and creates a maintenance report both to support the maintenance activity itself and to inform the operational managers about the maintenance history of the weather assets.
Inputs to and outputs from the ***Maintain Weather Assets*** activity are as follows:

- **INPUTS:** Maintenance Request (Weather)
- **OUTPUTS:** Maintenance Report (Weather)

6.3.1.1.1.3 Implement Weather Service Adjustment Plan

The ***Implement Weather Service Adjustment Plan*** activity executes the planned short-term tasks that may include the reconfiguration of assets or procedures within the existing design. This activity begins with the receipt of a selected adjustment plan that defines the objectives of the change. Operations personnel implement the selected adjustment and produce a reconfigured weather asset in accordance with operational procedures and funding constraints.
Inputs to and outputs from the ***Implement Weather Service Adjustment Plan*** activity are as follows:

- **INPUTS:** Adjustment Plan Selection (Weather)
- **OUTPUTS:** Reconfigured Asset (Weather)

6.3.1.1.2 Govern Weather Service

The ***Govern Weather Service*** activity oversees the creation and management of policies, business processes, and technologies; makes funding and resource allocations; and approves and monitors implementation plans. It begins with receipt of a request for or proposed/modification to a policy, business process or technology. This activity requires cross-organizational agreements and governance structures and leverages partner organizations to create standards and/or policies.
Inputs to and outputs from the ***Govern Weather Service*** activity are as follows:

- **INPUTS:** Policy/Standard Request (Weather), ICAO Standard, Industry Standard
- **OUTPUTS:** NextGen Weather Policy/Standard, Information Sharing Standards: Weather Information, Integrated Observation Governance Structure, Weather Information Regulatory Structure, NextGen Network-Enabled Virtual 4D Weather Cube Governance Structure, NextGen Network-Enabled Virtual 4D Weather Cube Governance Model, Network-Enabled Weather Observation Strategy

6.3.1.1.3 Plan Weather Service

The ***Plan Weather Service*** activity determines if existing weather assets are capable of meeting user needs. This activity begins with receipt of user needs, a change request, and/or performance reports and uses analytical and planning support tools, personnel, and facilities to evaluate the weather service performance in accordance with weather procedures. If a performance gap is identified and cannot be addressed through maintenance procedures, an improvement plan or adjustment plan is created. If the weather assets are modified as a result of implementing an improvement or adjustment plan, updates to the design documentation will be made. The *Plan Weather Service* activity is comprised of the following component activities:

- *Evaluate Long-Term Weather Assets,*
- *Evaluate Weather Service Modification Alternatives,*
- *Create Weather Plan,*
- *Conduct Weather R&D.*

Inputs to and outputs from the *Plan Weather Service* activity are as follows:

- **INPUTS:** Design Documentation (Weather), Market Information, User Needs (Weather), Performance Report (Weather), Change Request (Weather)
- **OUTPUTS:** Adjustment Plan (Weather), Policy/Standard Request (Weather), Improvement Plan (Weather), Method Algorithms for Wx Assim Decision-Making, Improve Weather Models

6.3.1.1.3.1 Evaluate Long-Term Weather Assets

The *Evaluate Long-Term Weather Assets* activity determines if existing weather assets are capable of meeting production and consumption needs of weather information. It begins by acquiring performance reports, market information, user needs and design documentation. This activity requires engineering and development funding and uses analytical and planning support tools, the Program Management Office personnel to produce an improvement request.
Inputs to and outputs from the *Evaluate Long-Term Weather Assets* activity are as follows:

- **INPUTS:** Performance Report (Weather), Market Information, User Needs (Weather), Design Documentation (Weather)
- **OUTPUTS:** Improvement Request (Weather)

6.3.1.1.3.2 Evaluate Weather Service Modification Alternatives

The *Evaluate Weather Service Modification Alternatives* activity identifies potential solutions to meet gaps in weather asset performance and conducts a cost/benefit analysis of each potential solution. It begins with the receipt of an improvement request or a change request and considers all user needs, existing design documentation, and R&D results, if available, to evaluate each alternative. This activity results in a recommended adjustment to solve short-term gaps or recommended improvement to address long-term gaps (if an adequate alternative is identified during the evaluation process). However, if an appropriate solution does not exist, this activity produces an R&D request to research and/or develop a potential solution. This activity uses analysis and planning support tools and Program Management Office personnel and requires engineering and development funding.
Inputs to and outputs from the *Evaluate Weather Service Modification Alternatives* activity are as follows:

- **INPUTS:** Improvement Request (Weather), User Needs (Weather), Design Documentation (Weather), Change Request (Weather), R&D Result (Weather)

- **OUTPUTS:** R&D Request (Weather), Recommended Improvement Alternative (Weather), Recommended Adjustment Alternative (Weather)

6.3.1.1.3.3 Conduct Weather R&D

The *Conduct Weather R&D* activity performs basic and applied research and development of new products, processes, procedures, and technology for use in improving the ability to provide weather information. It begins with an R&D request to produce detailed R&D results that support additional alternative analysis when determining possible enhancements to the weather service and/or solutions to identified problems. This activity requires R&D funding and uses weather personnel.
Inputs to and outputs from the *Conduct Weather R&D* activity are as follows:

- **INPUTS:** R&D Request (Weather)
- **OUTPUTS:** R&D Result (Weather), Method Algorithms for Wx Assim Decision-Making, Improve Weather Models

6.3.1.1.3.4 Create Weather Plan

The *Create Weather Plan* creates near-term and strategic plans to ensure user needs for producing weather information are met. It begins with a request for the development of a plan to address gaps in the ability to meet weather user needs. This activity requires funding and procedures and uses analytical and planning support tools and Program Management Office personnel to develop appropriate plans or requests. The *Create Weather Plan* activity is comprised of the following component activities:

- *Develop Short-Term Weather Service Adjustment Plan*
- *Develop Long-Term Weather Service Improvement Plan*.

Inputs to and outputs from the *Create Weather Plan* activity are as follows:

- **INPUTS:** Recommended Improvement Alternative (Weather), Recommended Adjustment Alternative (Weather), Design Documentation (Weather)
- **OUTPUTS:** Adjustment Plan (Weather), Policy/Standard Request (Weather), Improvement Plan (Weather)

6.3.1.1.3.4.1 Develop Short-Term Weather Service Adjustment Plan

The *Develop Short-Term Weather Service Adjustment Plan* activity identifies the sequence of tasks, their duration, dependencies, and resources required to accomplish the recommended alternative. It begins with the receipt of an adjustment recommendation and existing design documentation. This activity requires funding and procedures and uses the weather Program Management Office personnel and analytical and planning support tools to help develop an adjustment plan for the weather service.
Inputs to and outputs from the *Develop Short-Term Weather Service Adjustment Plan* activity are as follows:

- **INPUTS:** Recommended Adjustment Alternative (Weather), Design Documentation (Weather)
- **OUTPUTS:** Adjustment Plan (Weather)

6.3.1.1.3.4.2 Develop Long-Term Weather Service Improvement Plan

The *Develop Long-Term Weather Service Improvement Plan* activity identifies the sequence of tasks, their duration, dependencies, and resources required to accomplish the recommended alternative. It begins with the receipt of an improvement recommendation and existing design documentation. This activity requires funding and uses Program Management Office personnel and analytical and planning support tools to help develop an improvement plan, policy/standard request, or long-term strategy. Inputs to and outputs from the *Develop Long-Term Weather Service Improvement Plan* activity are as follows:

- **INPUTS:** Design Documentation (Weather), Recommended Improvement Alternative (Weather)
- **OUTPUTS:** Policy/Standard Request (Weather), Improvement Plan (Weather)

6.3.1.1.4 Implement Weather Service Improvement Plan

The *Implement Weather Service Improvement Plan* activity executes the planned tasks that improve the weather service by acquiring tools/facilities, hiring and training personnel, and/or developing new procedures. This activity begins with the receipt of an improvement plan that defines the objectives of the improvement. Program Management Offices lead the effort to implement the improvement plan and produce design documentation in accordance with policy, standards, and funding constraints. Inputs to and outputs from the *Implement Weather Service Improvement Plan* activity are as follows:

- **INPUTS:** Improvement Plan (Weather)
- **OUTPUTS:** Design Documentation (Weather), Operational Procedure (Weather), Facility (Weather), Operations Personnel (Weather), Weather Tool, Legacy Wx Apps Integrated with Network-Enabled Weather Information

6.3.1.1.5 Produce Weather Information

The *Produce Weather Information* activity collects and records weather conditions and their associated time and position via automated weather observation tools, sensors, and human weather observers. The activity begins with receipt of space, atmospheric and surface conditions, private weather information, time and position. The collected information is analyzed and translated into accurate weather and climatology information using weather models, processors, and algorithms to create near-term predictions and forecasts of the weather condition, adhering to weather policies and standards. The *Produce Weather Information* activity is comprised of the following component activities:

- *Observe Weather Conditions,*
- *Analyze Weather Information,* and
- *Forecast Weather*.

Inputs to and outputs from the *Produce Weather Information* activity are as follows:

- **INPUTS:** Space Conditions, Atmospheric Conditions, Surface Conditions, Private Weather Information
- **OUTPUTS:** Weather Information, Weather Forecast

6.3.1.1.5.1 Observe Weather Conditions

The *Observe Weather Conditions* activity collects atmospheric metrics (i.e. temperature, wind speed, humidity, wind direction, atmospheric pressure) in order to produce weather observations. This activity begins with an atmospheric condition being recorded using weather observation tools, sensors, and human observers, and then geospatially correlates the data to produce weather observations according to established weather policy and standards.
Inputs to and outputs from the *Observe Weather Conditions* activity are as follows:

- **INPUTS:** Space Conditions, Atmospheric Conditions, Surface Conditions
- **OUTPUTS:** Weather Observation

6.3.1.1.5.2 Analyze Weather Information

The *Analyze Weather Information* activity analyzes and translates weather observation data into weather and climatology information using weather models, processors, and algorithms. This activity begins with the receipt of weather observations and private weather information from weather observation tools, sensors, and human weather observers, and adheres to weather policies and standards to produce weather and climatology information. This information is supported by weather analysis tools, weather models and meteorologists.
Inputs to and outputs from the *Analyze Weather Information* activity are as follows:

- **INPUTS:** Weather Observation, Private Weather Information
- **OUTPUTS:** Weather Information, Climatology Information

6.3.1.1.5.3 Forecast Weather

The *Forecast Weather* activity creates near-term predictions of the weather condition, converting observations using numerical weather prediction models into weather forecasts. The weather forecasts are filtered for validity using statistical techniques to remove known biases in the model, or adjusted to take into account consensus among other numerical weather forecasts. It begins with acquiring weather and climatology information. This activity adheres to weather policies and standards and is supported by weather forecasting tools and predictive weather models to create weather forecasts.
Inputs to and outputs from the *Forecast Weather* activity are as follows:

- **INPUTS:** Weather Information, Climatology Information, Private Weather Information
  OUTPUTS: Weather Forecast

6.3.2 Stakeholders / Information Exchanges

Stakeholders/participants, along with the information exchanges (identifying the source and destination activities) associated with these Business Service / Operational Activities, are presented in the NextGen EA FY11 Weather OV-3 Information Exchange Matrix, which is summarized in the table below

	Information Exchange		Producer		Consumer	
Stakeholder	**Name**	**Description**	**Source**	**Source Activity**	**Destination**	**Destination Activity**
Aircraft Owner/Operator - Operations Personnel (Weather)	Design Documentation (Weather)	Design Documentation (Weather) describes the physical components, usages, restrictions, performance and other aspects of the Weather service assets.	Aircraft Owner/Operator	Implement Weather Service Improvement Plan	Operations Personnel (Weather)	Access Short Term Weather Service Performance. Maintain Weather Assets.
Aircraft Owner/Operator - Program Management Office (Weather)	Design Documentation (Weather)	Design Documentation (Weather) describes the physical components, usages, restrictions, performance and other aspects of the Weather service assets.	Aircraft Owner/Operator	Implement Weather Service Improvement Plan	Program Management Office	Develop Short-Term Weather Service Adjustment Plan. Develop Long-Term Weather Service Improvement Plan. Evaluate Weather Service Modification Alternatives. Evaluate Long -Term Weather Assets.
Governance Body (Weather) - Human Weather Observer	NextGen Weather Policy/Standard	NextGen Weather Policy/Standard is an authoritative guideline governing NextGen's receipt, processing, and distribution of weather information in areas (e.g. access rights, formatting and information validity)	Governance Body (Weather)	Govern Weather Service	Human Weather Observer	Observe Weather Conditions
Governance Body (Weather) - Human Weather Observer 2	NextGen Weather Policy/Standard	Private Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere at specified locations and projections of the state of the atmosphere at specified locations and times provided by a commercial organization.	Governance Body (Weather)	Govern Weather Service	Human Weather Observer	Observe Weather Conditions
Governance Body (Weather) - Meteorologist	NextGen Weather Policy/Standard	NextGen Weather Policy/Standard is an authoritative guideline governing NextGen's receipt, processing, and distribution of weather information in areas (e.g. access rights, formatting and information validity)	Governance Body (Weather)	Govern Weather Service	Meteorologist	Observe Weather Conditions. Forecast Weather. Analyze Weather Information
Governance Body (Weather) - Operations Personnel (Weather)	NextGen Weather Policy/Standard	NextGen Weather Policy/Standard is an authoritative guideline governing NextGen's receipt, processing, and distribution of weather information in areas (e.g. access rights, formatting and information validity)	Governance Body (Weather)	Govern Weather Service	Operations Personnel (Weather)	Maintain Weather Assets. Assess Short-Term Weather Service Performance
Governance Body (Weather) - Program Management Office	NextGen Weather Policy/Standard	NextGen Weather Policy/Standard is an authoritative guideline governing NextGen's receipt, processing, and distribution of weather information in areas (e.g. access rights, formatting and information validity)	Governance Body (Weather)	Govern Weather Service	Program Management Office (Weather)	Develop Short-Term Weather Service Adjustment Plan. Develop Long-Term Weather Service Improvement Plan.

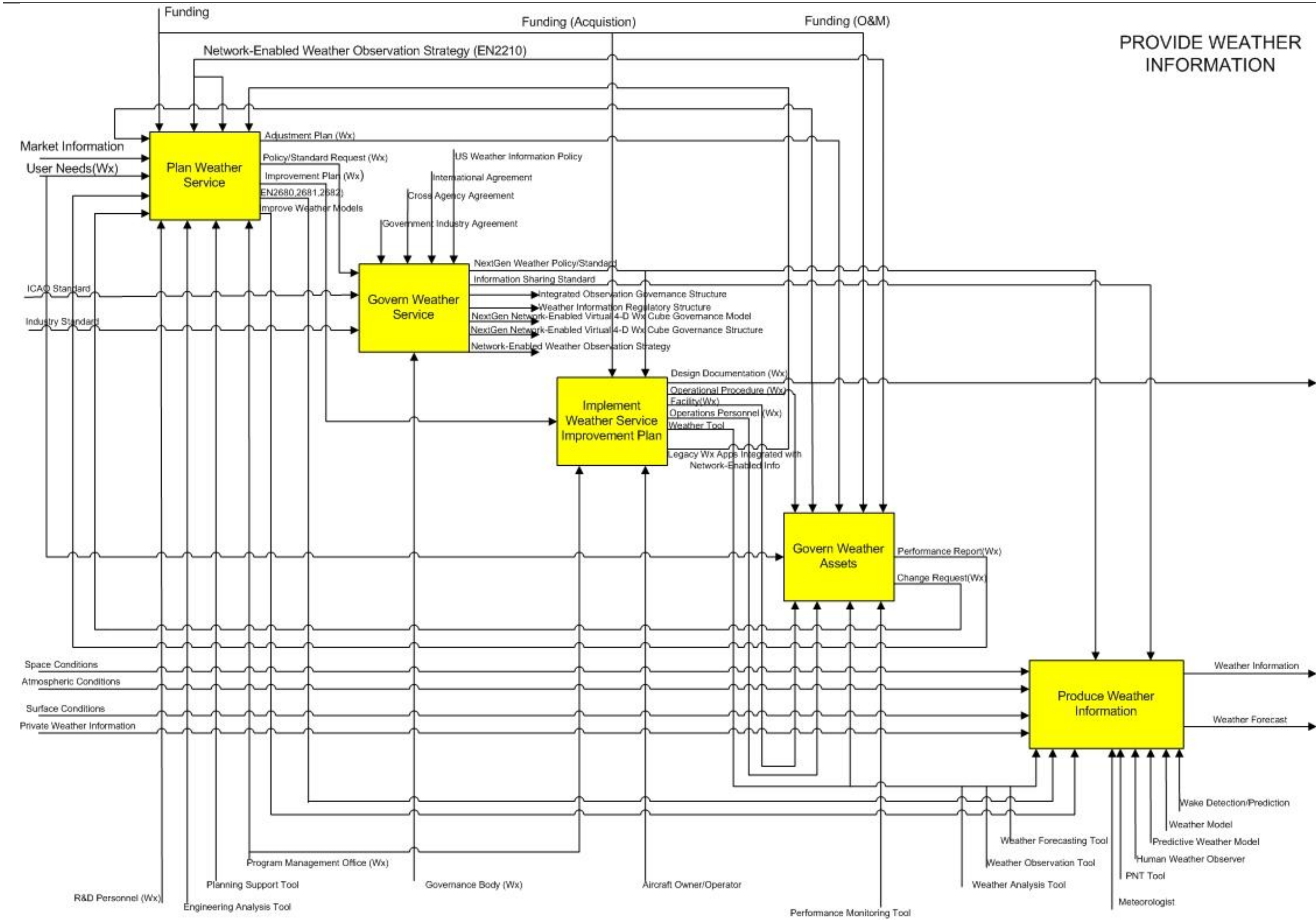
Human Weather Observer - Meteorologist	Weather Observation	A Weather Observation is an evaluation of one or more meteorological elements that describe the state of the atmosphere either at the earth's surface or aloft with associated time and position.	Human Weather Observation	Observe Weather Conditions	Meteorologist	Analyze Weather Information
Human Weather Observer - Meteorologist 2	Weather Observation	A Weather Observation is an evaluation of one or more meteorological elements that describe the state of the atmosphere either at the earth's surface or aloft with associated time and position.	Human Weather Observation	Observe Weather Conditions	Meteorologist	Analyze Weather Information
Industry Partners (Domestic & Foreign) - Governance Body (Weather)	Industry Standard	An Industry Standard is a common and repeated use of rules, conditions, guidelines or characteristics for products or related processes and production methods, and related management systems practices used by commercial organizations. (source: OMB Circular A-119)	Industry Partners (Domestic & Foreign)	External Activity	Governance Body (Weather)	Govern Weather Service
International Governance Body (Weather) - Governance Body (Weather)	ICAO Standard	An ICAO Standard is any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regulation of international air navigation and to which Contracting States will conform in accordance with the Convention; (Source: International Civil Aviation Organization)	International Governance Body (Weather)	External Activity	Governance Body (Weather)	Govern Weather Service
Meteorologist - National Defense Organization	Weather Information	Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere at specified locations and times.	Meteorologist	Analyze Weather Information	National Defense Organization	External Activity
	Weather Information	Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere with respect to temperature, precipitation, and wind. (Source: National Oceanic and Atmospheric Association)	Meteorologist	Forecast Weather	National Defense Organization	External Activity
Meteorologist -N extGen Information Consumer	Weather Forecast	A Weather Forecast is a prediction or an estimation based on special knowledge of the future state of the atmosphere with respect to temperature precipitation and wind (Source National Oceanic and temperature, precipitation, and wind. (Source: National Oceanic and Atmospheric Administration)	Meteorologist	Forecast Weather	NextGen Information Consumer	External Activity
	Weather Information	Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere at specified locations and times.	Meteorologist	Analyze Weather Information	NextGen Information Consumer	External Activity
National Defense Organization -M eteorologist	Weather Information	Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere at specified locations and times.	National Defense Organization	External Activity	Meteorologist	Forecast Weather

	Weather Observation	A Weather Observation is an evaluation of one or more meteorological elements that describe the state of the atmosphere either at the earth's surface or aloft with associated time and position.	National Defense Organization	External Activity	Meteorologist	Analyze Weather Information
Operations Personnel (Weather)-Progr am Management Office (Weather)	Change Request (Weather)	A Change Request (Weather) asks for a plan to address a gap between user needs and short-term performance of the Weather Service assets.	Operations Personnel (Weather)p ( )	Assess Short Term Weather Service Performance	Program Management Office (With Weather)	Evaluate Weather Service Modification Alternatives
	Performance Report (Weather)	A Performance Report (Weather) provides information about the ability of a service or its components to provide required outputs.	Operations Personnel (Weather)	Assess Short Term Weather Service Performance	Program Management Office (Weather)	Evaluate Long Term Weather Assets
Private Weather Service Provider -Meteor ologist	Private Weather Information	Private Weather Information is the collection of measurements, estimates, and projections of the state of the atmosphere at specified locations and projections of the state of the atmosphere at specified locations and times provided by a commercial organization.	Private Weather Service Provider	External Activity	Meteorologist	Anal e Weather Information Analyze Weather Information Forecast Weather
Program Management Office (Weather) -Aircr aft Owner/Operator Owner/Operator	Improvement Plan (Weather)	An Improvement Plan (Weather) is the executable strategy developed to address a user need that is outside the current capabilities of the Weather Service assets.	Program Management Office (Weather) (Weather)	Develop Long-Term Weather Service Improvement Plan Improvement Plan	Aircraft Owner/Operator	Implement Weather Service Improvement Plan
Program Management Office (Weather) -Gove rnance Body (Weather)	Policy/Standard Request (Weather)	A Policy/Standard Request (Weather) asks for a new or revised policy/standard.	Program Management Office (Weather)	Develop Long-Term Weather Service Improvement Plan	Governance Body (Weather)	Govern Weather Service
Program Management Office (Weather) -Oper ations Personnel (Weather)	Adjustment Plan (Weather)	An Adjustment Plan (Weather) is an outline of proposed changes and implementation updates to the Weather Service assets within their implementation updates to the Weather Service assets, within their current design parameters (e.g. reconfiguration of existing assets).	Program Management Office Program Management Office (Weather)	Develop Short Term Weather Service Develop Short-Term Weather Service Adjustment Plan	Operations Personnel (Weather)	Implement Weather Service Adjustment Plan Implement Weather Service Adjustment Plan Assess Short Term Weather Service Performance
	Operational Procedure (Weather)	An Operational Procedure (Weather) is an approved and published method and/or standard used to configure, maintain, and employ Weather Service assets.	Program Management Office (Weather) (Weather)	Implement Weather Service Improvement Plan	Operations Personnel (Weather)	Assess Short Term Weather Service Performance Maintain Weather Assets Implement Weather Service Adjustment Plan
	Design Documentation (Weather)	Design Documentation (Weather) describes the physical components, usages, restrictions, performance and other aspects of the Weather service assets.	Program Management Office (Weather)	Implement Weather Service Improvement Plan	Operations Personnel (Weather)	Assess Short Term Weather Service Performance Maintain Weather Assets
Program Management Office	R&D Request (Weather)	An R&D Request (Weather) asks for specific outcomes from research and an R&D Request (Weather) asks for specific outcomes from research and development due to a lack of	Program Management Office (Weather)	Evaluate Weather Service Modification Alternatives	R&D Personnel	Conduct Weather R&D

(Weather) -R&D Personnel		current available alternatives.				
R&D Personnel -Program Management Office (Weather)	R&D Result (Weather)	An R&D Result (Weather) is an outcome achieved from research and development.	R&D Personnel	Conduct Weather R&D	Program Management Office (Weather)	Evaluate Weather Service Modification Alternatives

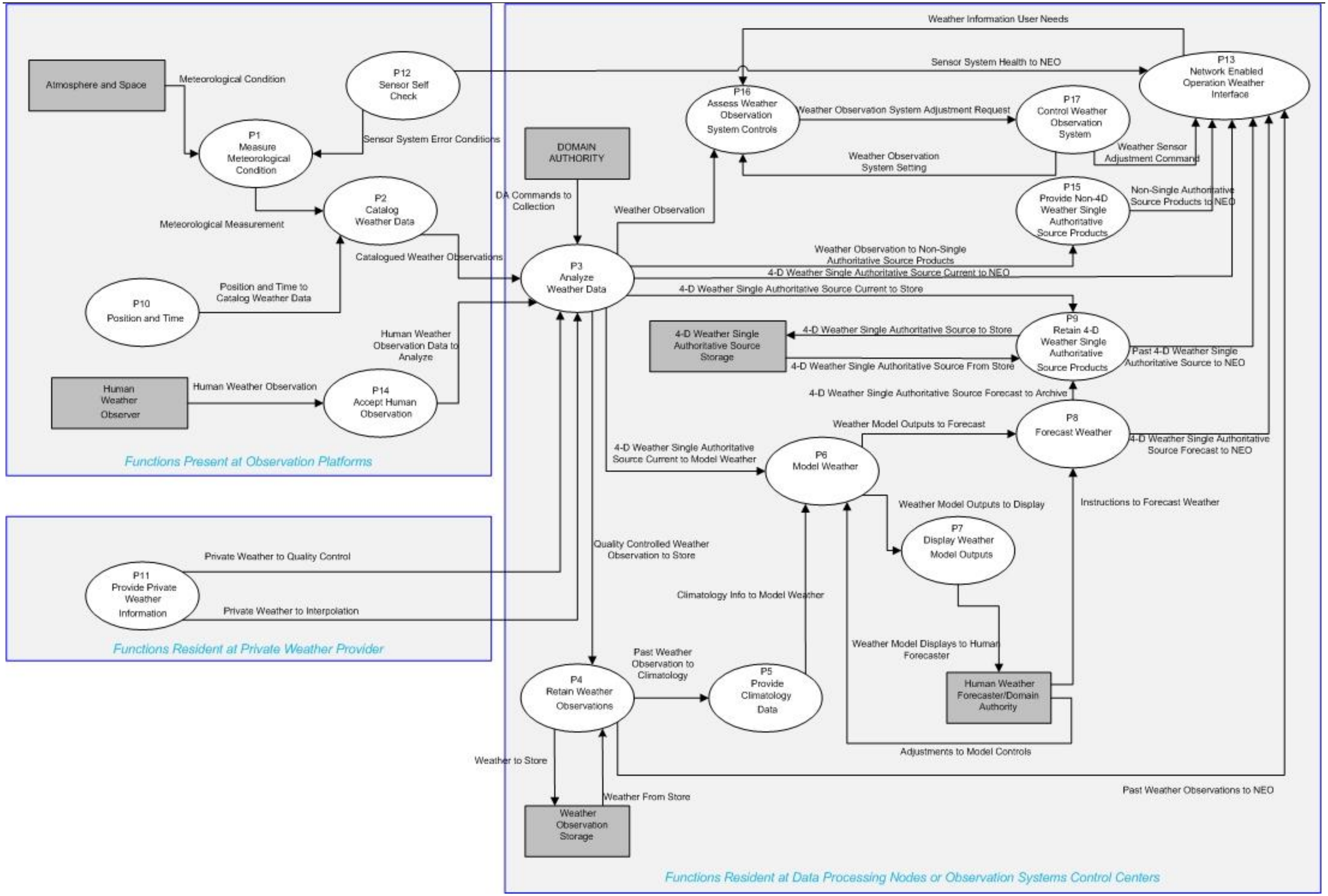
6.3.3 Specific Data Flows

More detailed flows of information between weather related operational activities are presented in the NextGen EA OV-5 Activity Model diagrams. The *Provide Weather Information* activity is comprised of several functions detailed in the above section and visualized in the figure below.


PROVIDE WEATHER INFORMATION
Funding
Funding (Acquisition)
Funding (O&M)
Network-Enabled Weather Observation Strategy (EN2210)
Market Information
User Needs(Wx)
Plan Weather Service
Adjustment Plan (Wx)
Policy/Standard Request (Wx)
Improvement Plan (Wx)
EN2680,2681,2682)
Improve Weather Models
US Weather Information Policy
International Agreement
Cross Agency Agreement
Government Industry Agreement
ICAO Standard
Industry Standard
Govern Weather Service
NextGen Weather Policy/Standard
Information Sharing Standard
Integrated Observation Governance Structure
Weather Information Regulatory Structure
NextGen Network-Enabled Virtual 4-D Wx Cube Governance Model
NextGen Network-Enabled Virtual 4-D Wx Cube Governance Structure
Network-Enabled Weather Observation Strategy
Implement Weather Service Improvement Plan
Design Documentation (Wx)
Operational Procedure (Wx)
Facility(Wx)
Operations Personnel (Wx)
Weather Tool
Legacy Wx Apps Integrated with Network-Enabled Info
Govern Weather Assets
Performance Report(Wx)
Change Request(Wx)
Space Conditions
Atmospheric Conditions
Surface Conditions
Private Weather Information
Produce Weather Information
Weather Information
Weather Forecast
Wake Detection/Prediction
Weather Model
Predictive Weather Model
Human Weather Observer
PNT Tool
Meteorologist
Weather Forecasting Tool
Weather Observation Tool
Weather Analysis Tool
Performance Monitoring Tool
Program Management Office (Wx)
Planning Support Tool
Governance Body (Wx)
Aircraft Owner/Operator
R&D Personnel (Wx)
Engineering Analysis Tool

Initial efforts have been performed by the NextGen EA team to further describe weather-related system functions required to support the operational activities and their inter-relationships (and information flows). These are presented in EA artifact SV-4, the System Functionality Description, presented below.

The key to a successful NextGen weather program is the functionality related to System Function P13, Network Enabled Operation Weather Information, which is the driving functionality requiring the NextGen 4D Cube.


Functions Present at Observation Platforms
Atmosphere and Space
Meteorological Condition
P12 Sensor Self Check
Sensor System Error Conditions
P1 Measure Meteorological Condition
Meteorological Measurement
P2 Catalog Weather Data
Catalogued Weather Observations
P10 Position and Time
Position and Time to Catalog Weather Data
Human Weather Observation Data to Analyze
Human Weather Observer
Human Weather Observation
P14 Accept Human Observation
Functions Resident at Private Weather Provider
P11 Provide Private Weather Information
Private Weather to Quality Control
Private Weather to Interpolation
Functions Resident at Data Processing Nodes or Observation Systems Control Centers
Weather Information User Needs
Sensor System Health to NEO
P13 Network Enabled Operation Weather Interface
P16 Assess Weather Observation System Controls
Weather Observation System Adjustment Request
P17 Control Weather Observation System
Weather Sensor Adjustment Command
Weather Observation System Setting
DOMAIN AUTHORITY
DA Commands to Collection
Weather Observation
P15 Provide Non-4D Weather Single Authoritative Source Products
Non-Single Authoritative Source Products to NEO
P3 Analyze Weather Data
Weather Observation to Non-Single Authoritative Source Products
4-D Weather Single Authoritative Source Current to NEO
4-D Weather Single Authoritative Source Current to Store
4-D Weather Single Authoritative Source Storage
4-D Weather Single Authoritative Source to Store
4-D Weather Single Authoritative Source From Store
P9 Retain 4-D Weather Single Authoritative Source Products
Past 4-D Weather Single Authoritative Source to NEO
4-D Weather Single Authoritative Source Forecast to Archive
P8 Forecast Weather
Weather Model Outputs to Forecast
4-D Weather Single Authoritative Source Forecast to NEO
4-D Weather Single Authoritative Source Current to Model Weather
P6 Model Weather
Weather Model Outputs to Display
Instructions to Forecast Weather
P7 Display Weather Model Outputs
Quality Controlled Weather Observation to Store
Climatology Info to Model Weather
Weather Model Displays to Human Forecaster
Human Weather Forecaster/Domain Authority
Past Weather Observation to Climatology
P4 Retain Weather Observations
P5 Provide Climatology Data
Adjustments to Model Controls
Weather to Store
Weather From Store
Past Weather Observations to NEO
Weather Observation Storage

6.3.4 Business Use Cases

From these data flows, more detailed use cases are being developed by NextGen enterprise architects. Specific use cases related to the IT architecture are captured in the IT Conops document.

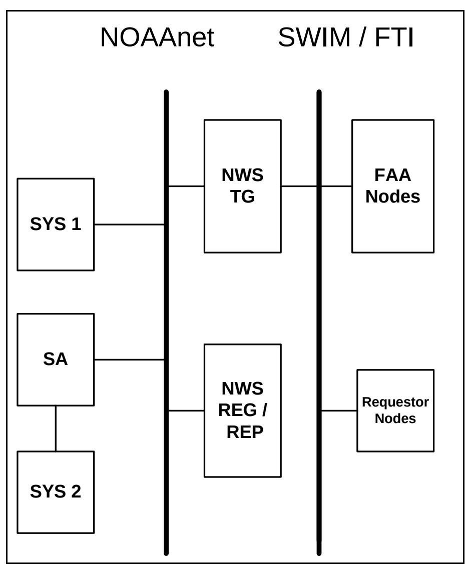
6.4 Architecture Options

This section provides an overview of three target architecture options that NOAA NWS could implement to meet its organizational responsibilities with regard to the 4-D Weather Cube. The architectures described herein represent three levels of development ranging from a minimum development effort up to a complete system of systems approach. Each section includes a high-level description of the target architecture along with discussion of how each option meets the requirements and the pros and cons of each approach. In the drawings presented for each option, there are only two data provider systems represented (SYS 1 and SYS 2), however this is just representational and the number of provider systems will be much larger in reality.

6.4.1 Option 1 – Minimal Development Approach

6.4.1.1 High Level Architecture Overview

The first target architecture option involves a relatively minimal development effort on the part of the NWS and is essentially a "status quo" approach. This minimal development option would implement a minimal amount of service adaption to accommodate format conversions from existing legacy provider systems and would accept data from new systems developed to provide data in the prescribed format for ingest into the Cube. The figure below illustrates the basic architecture of this minimal development approach.



In this architecture, data provider systems would feed data directly through NOAAnet into the NWSTG, which will act as the NOAA/NWS portal to the FAA for Cube data. In the drawing, SYS 1 represents data provider systems that will be capable of providing data natively in the format used by the Cube and SYS 2 represents legacy systems that will not provide natively formatted Cube data. Data providers falling under the category of SYS 2 would be provided with a newly developed service adapter (SA) to accept weather data in the legacy format and convert that data into the format used by the Cube.

As part of this architecture option, NWS would stand up a NWS registry / repository to provide various information related to data discovery, support of data access, weather product metadata, and support for build time and run time discovery. The NWSTG would act as the conduit to the FAA's SWIM/FTI infrastructure to handle requests from and data delivery FAA nodes handling requests within the FAA enterprise architecture.

6.4.1.2 Suitability to Requirements

The minimal development architecture would meet the essential requirements of the Cube, primarily those for offering data discovery and data access. However, much of functional requirements would not be implemented on the NOAA NWS side of the architecture and would instead need to be built into FAA nodes on the FAA side. Some of these requirements would likely include data subsetting, management of subscription services, any further data processing required, data caching, system monitoring and reporting, security, and user access management. This architecture approach also does not meet requirements surrounding the "system of systems" concept as well as those for a net-centric / service oriented architecture (SOA).

6.4.1.3 Pros / Cons

The primary advantage to this architecture is that it requires the least development effort on the part of NOAA NWS. However, there are numerous obvious drawbacks to this minimal development approach. This architecture may not support push, or subscription, services on the NWS side unless it is supported within the data provider systems. Additional support for subscription services would need to be implemented and managed by the FAA in their FAA nodes, as well as the other functions not supported on the NWS side of the architecture such as data caching, system monitoring, security, and user access management.

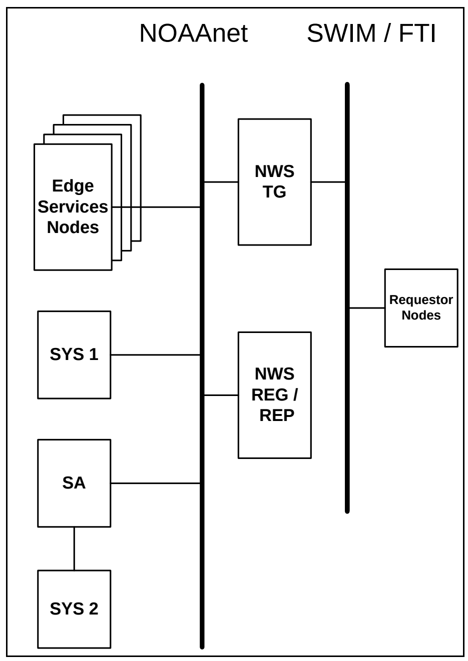
Another disadvantage to this approach is that it is not truly net-centric nor would it be implemented based on a service oriented architecture (SOA). As a result, from the NWS side of the architecture, it would likely not implement or support interactions using web coverage services (WCS) or web feature services (WFS), which would limit the overall functionality of the interfaces with the FAA data consumers and systems that are WCS and WFS capable. A further disadvantage is that the data provider systems are not tightly managed as would be the case if they were connected to highly functional edge services instead of directly connected into NOAAnet and making their data available from the NWSTG.

6.4.2 Option 2 – Centralized NOAA Approach

6.4.2.1 High Level Architecture Overview

The second target architecture option would make use of centralized edge services nodes on the NOAA NWS side of the architecture to implement much of the functionality required to support the Cube. This approach would connect legacy systems through service adapters to NOAAnet and new systems directly through NOAAnet to the NWSTG as in the minimal development architecture, but would add edge services in a centralized configuration within NOAA NWS. These edge services nodes would then be able to accommodate much of the functionality not realized by NWS systems in the minimal development approach. Some of these functions could include data subsetting, management of subscription services, any further data processing required, data caching, system monitoring and reporting, security, and user access management. These edge services may be able to be built to accommodate interaction through WCS and WFS, possibly by incorporating FAA provided reference implementations.

As before in the minimal development architecture, NWS would implement a registry / repository and request and data flow would be through the NWSTG into the FAA's SWIM / FTI infrastructure to the requesting nodes within the FAA.



6.4.2.2 Suitability to Requirements

The centralized edge services architecture meets the basic Cube requirements and goes further than the minimal development approach in implementing a greater set of functional requirements within the edge services on the NWS side of the architecture. However, there are still requirements that this approach may not cover, or may only cover partially. For example, this architecture approach does not meet requirements surrounding the highly distributed "system of systems" concept and may not support the tenets of net-centricity or service oriented architectures (SOA).

6.4.2.3 Pros / Cons

The primary advantage to the centralized edge services architecture is that much of the functionality not implemented by the NWS in the minimal development approach is now built into the edge services operating within the NWS domain. This approach still has legacy data providers and newly developed / modified data provider systems that are operating in an environment that is not tightly controlled, as will be the case in the third option below wherein these data providers will be connected first into distributed edge services that will broker operations between data provider systems and the Cube. Another disadvantage is that the edge services are centralized and therefore would not be implemented as a system of systems, and subsequently would not benefit from some of the inherent characteristics of a distributed system of systems, such as distributed load balancing, and higher availability through geographic redundancy.

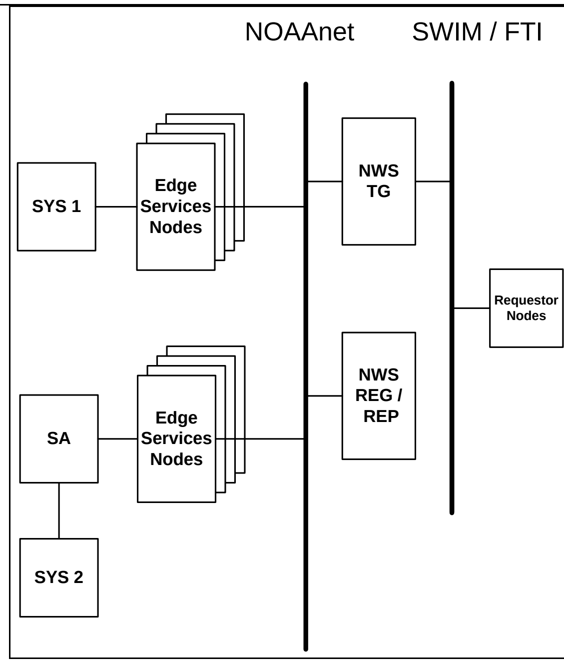
6.4.3 Option 3 – True System of Systems Approach

6.4.3.1 High Level Architecture Overview

The third architecture option is one that implements a "system of systems" approach. A system of systems is typically a fairly complex, highly distributed architecture that brings together numerous separate systems to meet a common set of information processing and distribution requirements. The system of systems approach will ideally net a large, loosely coupled set of systems that would have a greater functionality than the simple sum of the underlying parts.

For the NWS, this architecture approach would use numerous edge services nodes in a widely distributed fashion to implement the functional requirements of the NWS side of the Cube architecture. Data provider systems will be connected first into edge services that will more tightly manage interactions between providers and the other parts of the Cube architecture. There will still be legacy data provider systems that will require service adapters to perform required data format translations, however in this architecture that service adaptor functionality could reside in or near the edge services nodes.

The edge services will implement numerous services and/or modules to fulfill most if not all of the functional requirements. This architecture will be net-centric based on SOA principles and will be capable of accommodating interactions with the FAA WCS and WFS implementations. The architecture itself will be agile and scalable, allowing relatively easy changes to existing services and data products, as well as the addition of new data providers and data products. Again, the NWS will stand up a registry / repository, but in the case of the system of systems approach, this registry / repository will most likely be part of a larger, federated registry / repository distributed across systems in a manner that will be transparent to the end users. Also, it is anticipated that the NWSTG will again serve as the primary connection point between NOAAnet and the FAA's SWIM / FTI.



Some of the goals of implementing a system of systems architecture from an infrastructure perspective are as follows:

- Provide a loosely-coupled, distributed computing system for exchange of weather information
- Allow (via loose coupling) for technical refresh of different components of the distributed system at different times
- Make interface definitions dynamically available via Web Services Description Language (WSDL) or some similar technology that does not restrict programming languages or otherwise dictate client implementations.
- Support redundancy by implementing the virtual data base in multiple physical locations (transparent to data providers and customers) with overlapping synchronized data sets
- Support scalability so that new physical data repositories can be added as needed

6.4.3.2 Suitability to Requirements

The full systems of systems architecture will provide the widest coverage of the functional requirements for the NWS implementation of the 4-D Weather Cube. In addition to the basic requirements for data discovery and data access, this architecture approach will provide services to meet requirements for governance, security, agility, monitoring, fault tolerance, net-centricity / SOA implementation, support for FAA WCS / WFS, support of the SAS, user management, availability, archiving/logging, and quality of service.

6.4.3.3 Pros / Cons

The primary advantages of the systems of systems architecture approach are its flexibility and ability to meet the largest amount of the Cube functional requirements. Further advantages are realized through the distributed system of systems approach that would provide for a federated registry / repository, system load balancing, and higher availability. Disadvantages include a higher level of development work than the other approaches. Typically a system of systems architecture will not be capable of relying as heavily on Commercial-Off-The-Shelf (COTS) products as a single system might be able to do. This is partly because the systems being integrated into the larger system of systems have not been designed in a manner that would easily accommodate interoperability between them, i.e., these systems will typically have been designed and implemented as stove pipes to fulfill their particular mission and serve a specific set of users. Therefore, there will be a significant effort to develop the governing, management, and other services within the system of systems to achieve this originally un-planned for interoperability. Another disadvantage here is the time and cost to implement, which will also be greater than that expected for the other architecture approaches.

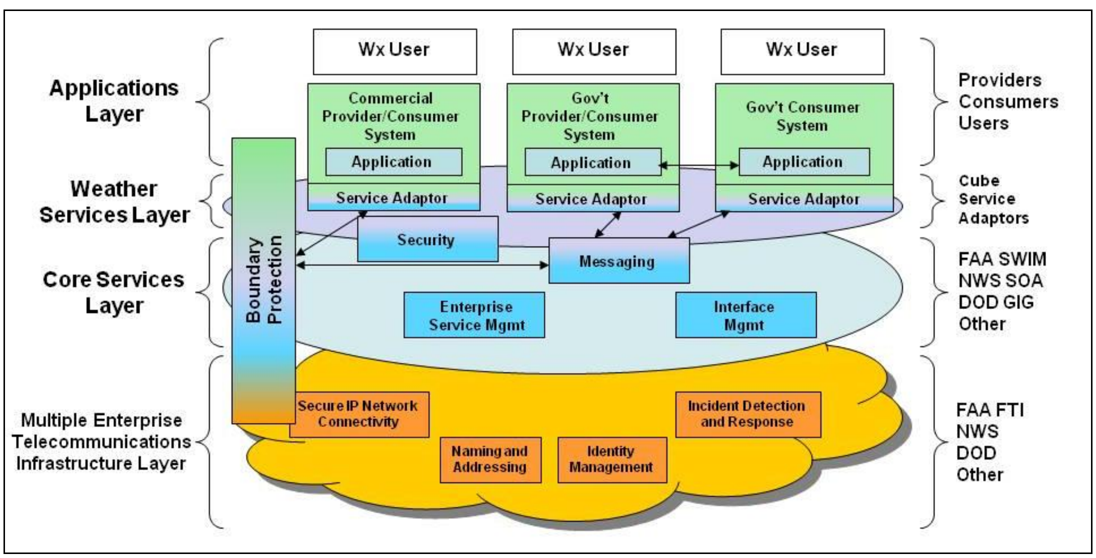
6.5 High Level Functional Architecture of Selected Approach

6.5.1 General Layered Approach

The proposed NOAA architectural approach builds on a layered model proposed in the FAA NNEW developed 4-D Weather Data Cube White Paper. This allows for a structured hierarchical foundation and merges nicely with the FAA architecture approach.

The framework is comprised of four layers

1. Multiple Enterprise Telecommunications Infrastructure Layer
2. Core Services Layer
3. Weather Services Layer
4. Application Layer



6.5.1.1 Telecommunications Layer

The Telecommunications layer provides the physical telecommunications networking within and between the multiple participating enterprises. It provides the raw network connectivity and associated monitoring infrastructure which consists of a secure Internet Protocol (IP) network, with standard naming and addressing management, routine network incident detection and response, and identity management.

6.5.1.2 Core Services Layer

The Core Services Layer is comprised of NOAA's SOA-based System of Systems. This System of Systems infrastructure and its components ensure the interoperability of and allow the network enabling of the various Application Layer business systems via web services through the use of open standards (HTTP, XML, REST, SOAP, etc). Handling of adhoc requests as well as subscription-based services is supported by the Core Services. Routine system, administrative, and redundancy management, security and access control, as well as other functions such as error handling, storage, back-up and archival management are also embedded in the functions provided by the Core Services Layer.

Additionally, both design-time and runtime service discovery are supported via the use of a federated registry. At design-time, a service provider or consumer uses the registry to publish or discover information about a service, including all the details needed to build server and client-side software that conforms to the standard interface. At runtime, applications discover instance-specific information, such as the individual addresses of each service or whether the information has been determine to be part of the SAS. Where appropriate, reuse of various network-facing components is intended to leverage the advantages of the SOA environment, and to further ensure commonality across the various participating services.

6.5.1.3 Weather Services Layer

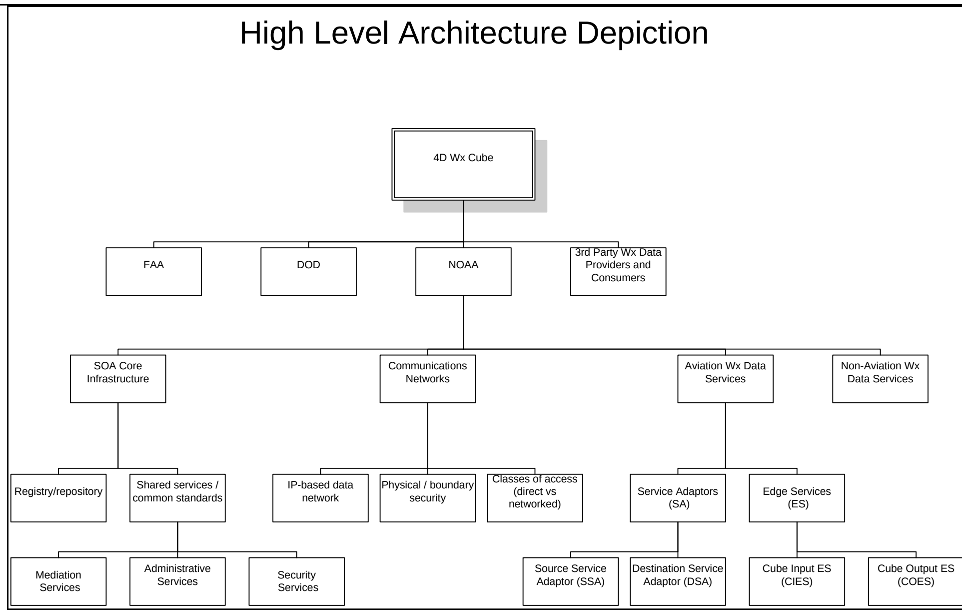
The weather domain concerns of the Cube are addressed by the Weather Services Layer. The Weather Services Layer enhances the capabilities of the Core Services Layer with the addition of weather specific standards and formats. It also includes any service adaptation required to convert weather data into a format for ease of storage, discovery, manipulation, geographic and temporal-based filtering, and dissemination throughout the Cube environment.

6.5.1.4 Applications Layer

The Application Layer consists of weather data users and systems that will provide data to and consume data from the Cube. These applications/systems will become the business services of the Cube.

6.5.2 Architecture Functional Components

The overall Cube architecture is composed of functional components from various entities and organizations, as presented in the figure below. These include the FAA, DoD, NOAA, and other potential 3rd party Wx data providers and consumers.



The NOAA contribution to the Cube is composed of its related communications network infrastructure (including an IP-based data network, appropriate physical and boundary security, and the potential implementation of multiple classes of access for differing performance requirements), its SOA core infrastructure, and the aviation and non-aviation weather services it intends to provide. To enable access to its weather services, the following functional components have been defined and are addressed in more detail throughout the remaining architecture discussions that follows:

- Service Adaptors (SA)
  - Source Service Adaptor (SSA) - Performs processing to:
    - Transform native or legacy source wx data that is required for publishing to the Wx Cube into a format appropriate for ease of access via Cube Input Edge Services (e.g., transformed into one of several supported standards), and possibly
    - To make source wx data available to Cube Input Edge Services via a convenient and reliable network accessible means (e.g., web services-based communications) where such a means may not currently exist.
  - Destination Service Adaptor (DSA) - Performs processing to:
    - Transform wx data from a format appropriate for ease of access by Cube Output Edge Services into a native or legacy format compatible with the destination system
    - Support a mechanism to request access to data residing within the Cube
- Edge Services
  - Cube Input Edge Services (CIES)
    - Allows remote access to the wx data (or subsets thereof) via WCS/WFS/other web services.
    - Provides for the ingest of wx data required by the Wx Cube (obtained either directly from the native source, or via a Service Adaptor which is the most likely case for most data sources initially)

    - Performs the necessary processing and local storage, as well as administrative and security functions
- Cube Output Edge Services (COES)
    - Provides for the request and retrieval of Wx Cube data from remote WCS/WFS/other web services
    - Performs the necessary processing and local storage, as well as administrative and security functions
    - Allows access to the data by the requesting local destination system.

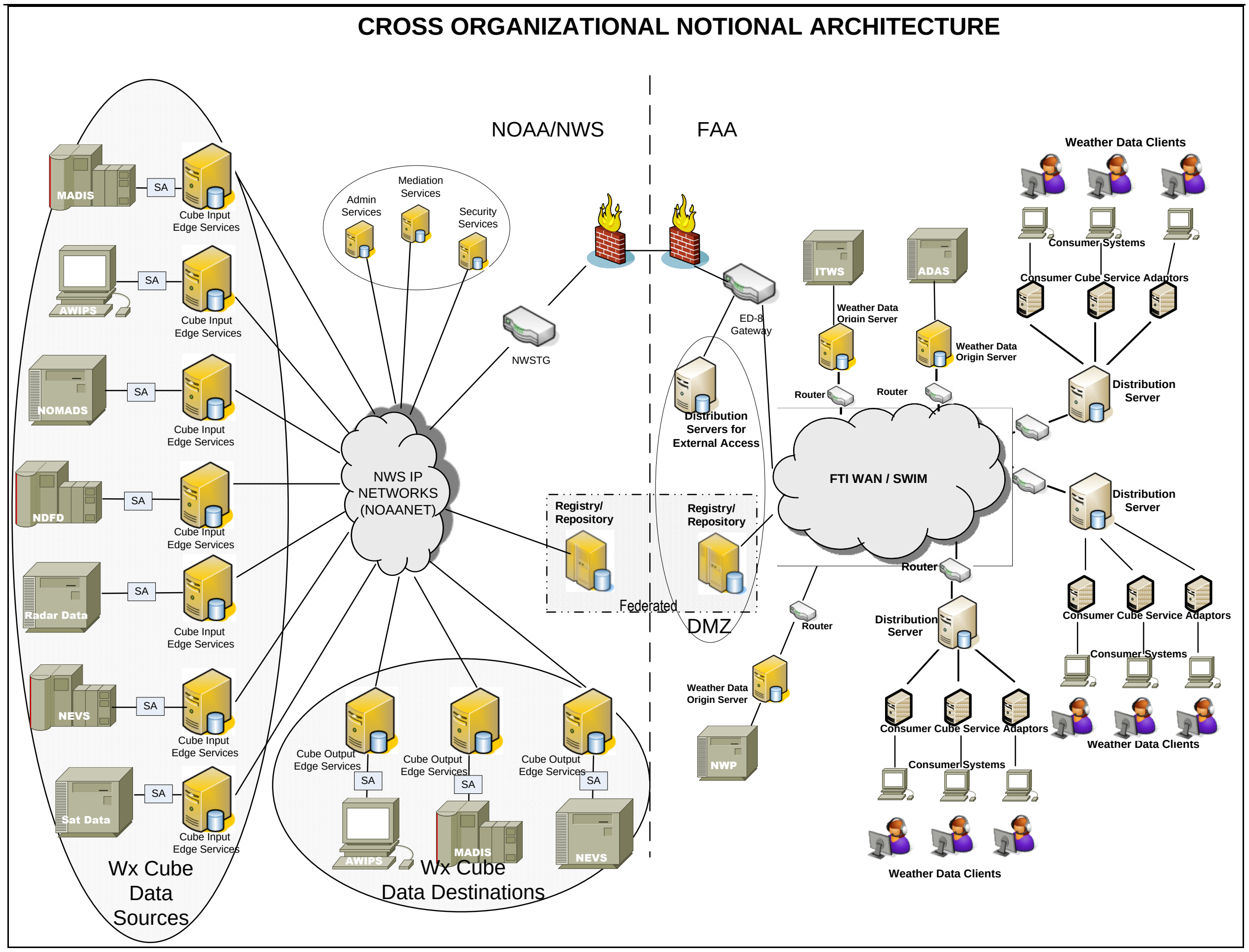
It is worth mentioning here that as a goal, the WCS/WFS Reference Implementation (RI) efforts underway by the FAA will be taken into serious consideration as either a model on which NOAA COES and CIES design efforts will be based, or may be used in part or in total where appropriate in order to leverage these extensive efforts performed to date. Alternatively, DoD efforts in the development of JMBL and WMS reference implementations are also under consideration as a baseline on which to design and build NOAA's COES and CIES.

6.5.3 Architecture Overview

In line with the System of Systems approach, each candidate weather system included in the Cube will be treated as a separate node, either serving as a Wx Cube Data Source and offering data for use by Cube participants (via a CIES), or serving as a Wx Cube Data Destination, obtaining data from other Cube participants (via a COES), or in some cases, serving as both.

A variety of other services / components may be required to support Cube operations. Security Services will provide for the exchange / storage of security and trust related shared information (tokens, keys, etc) as well as security processing to include encryption, decryption, authentication, and boundary security. Security is intended to be provided on several levels, including: transport layer communications, application, message and data. Distributed (or possibly centralized) administrative functions will be necessary to control, operate, and monitor all the systems that comprise the Cube. These functions are intended to be provided via a series of web service-based Administrative Services. In order to allow for the interoperability between otherwise incompatible source (producer) and destination (consumer) systems, Mediation Services may be required to translate between incompatible data formats and / or incompatible data exchange protocols.

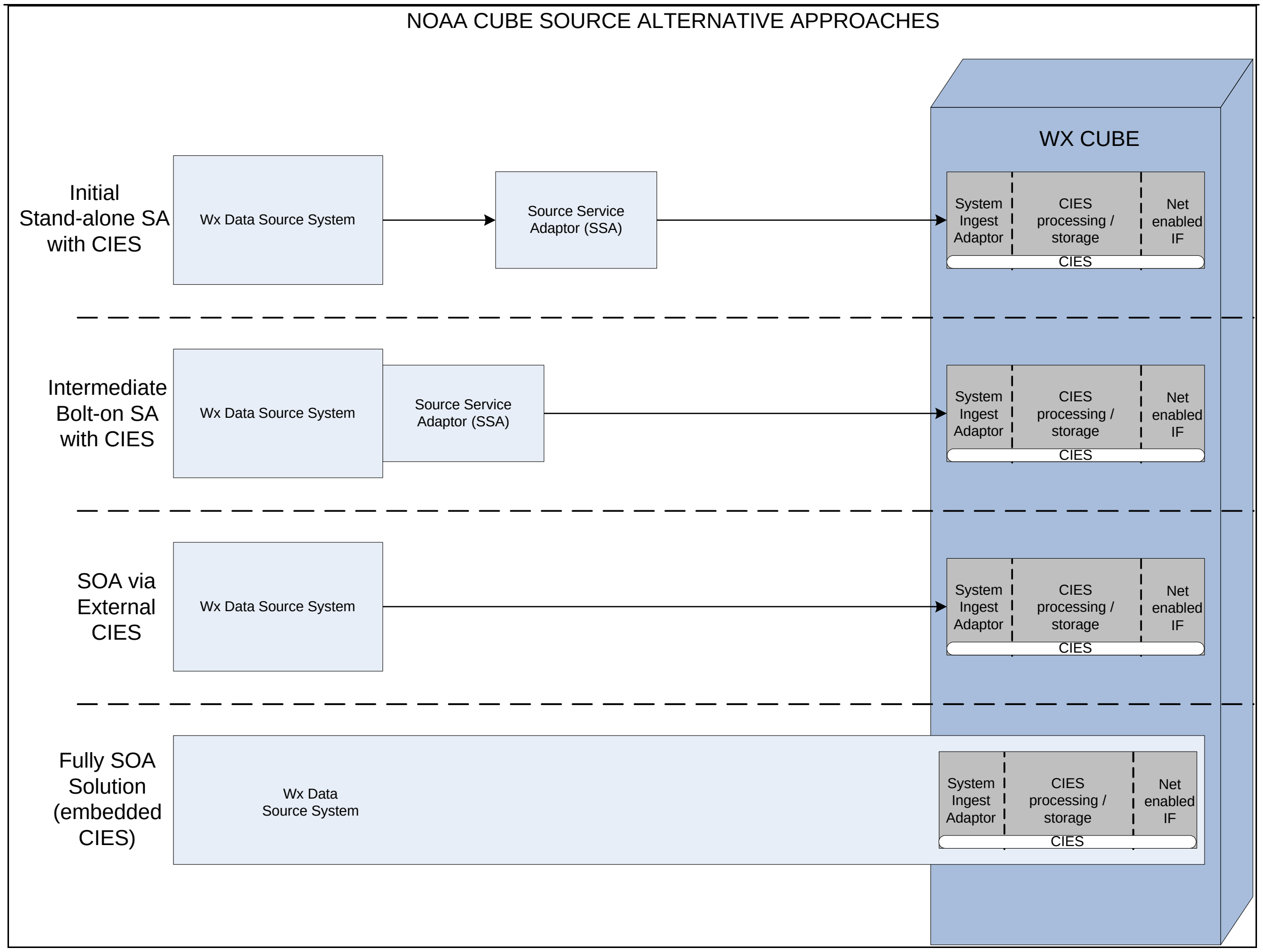
Additionally, the Registry/ Repository will also be a separate node and will be federated with other Registry/Repositories (e.g., the FAA Reg/Rep). These nodes will be net-enabled via appropriate Web-services, and be accessible via an IP-based communication infrastructure (NOAANET). This IP-based communications infrastructure will connect to the FAA portion of the Cube via appropriate boundary protection devices and security services. This will most likely be performed via connections from the NWSTG to various FAA ED-8 gateway locations. The figure below presents a cross-organization view of this notional architecture as it is currently envisioned.



Although the figure above shows each weather data system depicted and its respective interface component to the Cube (i.e., CIES and COES) as independent systems (i.e., NDFD is provided Cube access via a CIES to publish its data to the Cube) interfacing via a standalone Service Adaptor, a variety of alternative approaches are being considered which may be supported concurrently within the Cube.

6.5.3.1 Alternative Source Implementations

The figure below depicts several alternative approaches for NOAA Wx Cube source implementations. This alternative approaches may be deployed as transitional strategies to gradually bring legacy weather systems into the Cube, starting with minimal impacts to the legacy system (most if not all processing related to making the system Cube-enabled is done external to the legacy system), and progressing through approaches that either necessitate limited or major redevelopment of such legacy systems. New systems may be designed to embed the necessary Cube-enabling technologies internally, as the last approach shows.



Initial Stand-alone SA with CIES – In this case, the Wx Data Source System has legacy data that is in a format that is not easily adapted by its corresponding CIES. Therefore, a stand-alone Source Service Adaptor (SSA) is introduced to transform the legacy data into a format more appropriate for the CIES.

Intermediate Bolt-On SA with CIES – Alternatively, in this case, the Wx Data Source System may be modified to include the transformation processing of the legacy data into a more usable format either internal to the source system, or via a tightly coupled, "bolted on" Source Service Adaptor (SSA).

SOA via External CIES – In this case, an independent CIES, which has ready access to its corresponding Wx Data Source System, provides the interface to the Cube.

Fully SOA Solution (embedded CIES) - In this case, the CIES function is actually tightly coupled to the Wx Data Source System and essentially embedded into the source system.

In each case, the CIES is composed, in general, of the following:

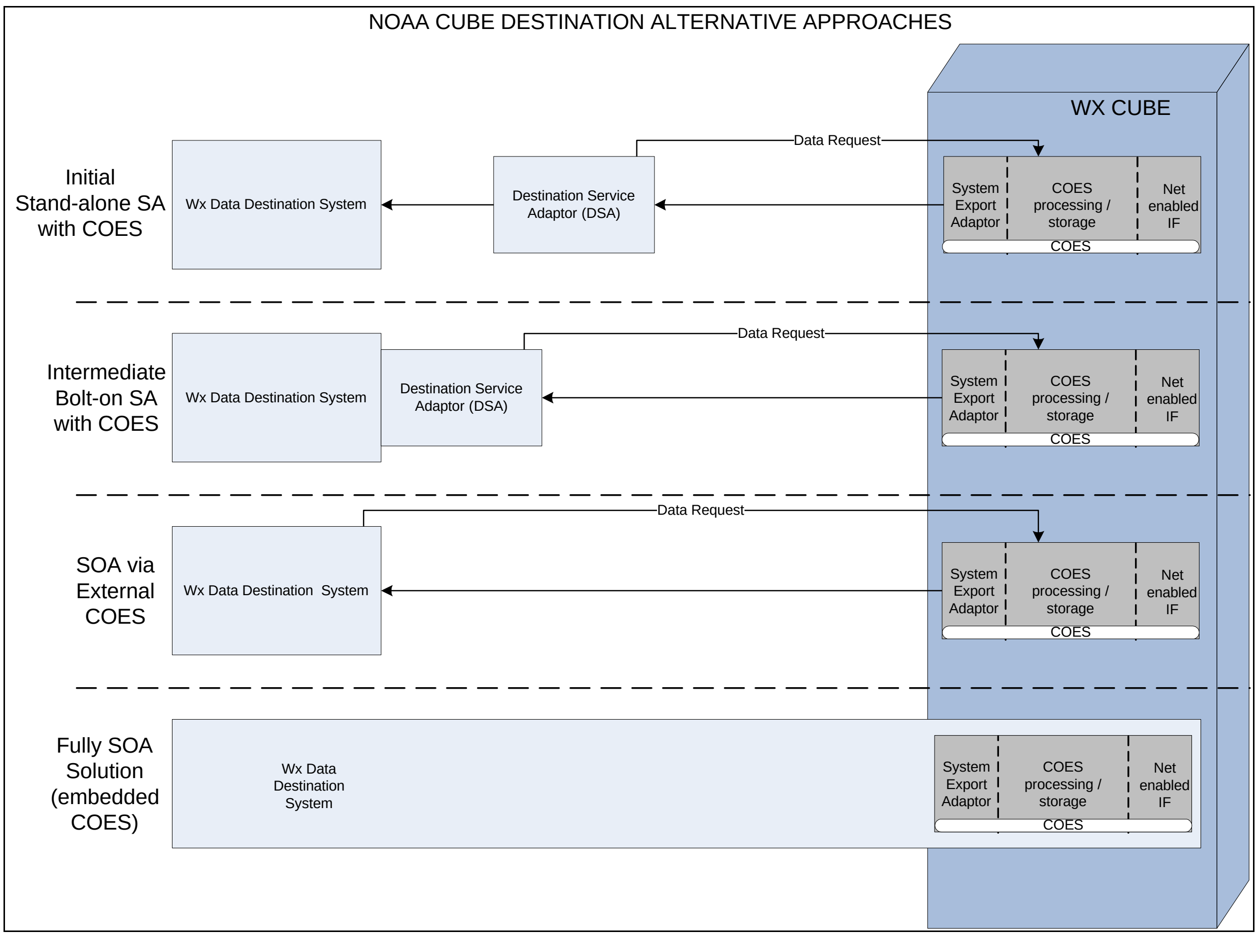
- System Ingest Adaptor – Provides an interface to the Wx Data Source System data and any required ingest processing
- CIES Processing / Storage – Performs the majority of processing required by the CIES, as well as the storage management

- Net-Enabled Interface – Supports the interface to the Cube, handling requests.

A more detailed discussion of the functionality contained within the CIES is presented further in this document.

6.5.3.2 Alternative Destination Implementations

The figure below depicts several alternative approaches for NOAA Wx Cube destination implementations.



Initial Stand-alone SA with COES – In this case, the Wx Data Destination System requires data that in a format that is not easily transformed by its corresponding COES. Therefore, a stand-alone Destination Service Adaptor (DSA) is introduced to transform data received by the COES from the Cube into a format more appropriate for the Wx Data Destination System.

Intermediate Bolt-On SA with COES – Alternatively, in this case, the Wx Data Destination System may be modified to include the transformation processing of the Cube data into a more usable format either internal to the destination system, or via a tightly coupled, “bolted on” Destination Service Adaptor (DSA).

SOA via External COES – In this case, an independent COES, which has ready access to its corresponding Wx Data Destination System, provides the interface to the Cube.

Fully SOA Solution (embedded COES) - In this case, the COES function is actually tightly coupled to the Wx Data Destination System and essentially embedded into the destination system.

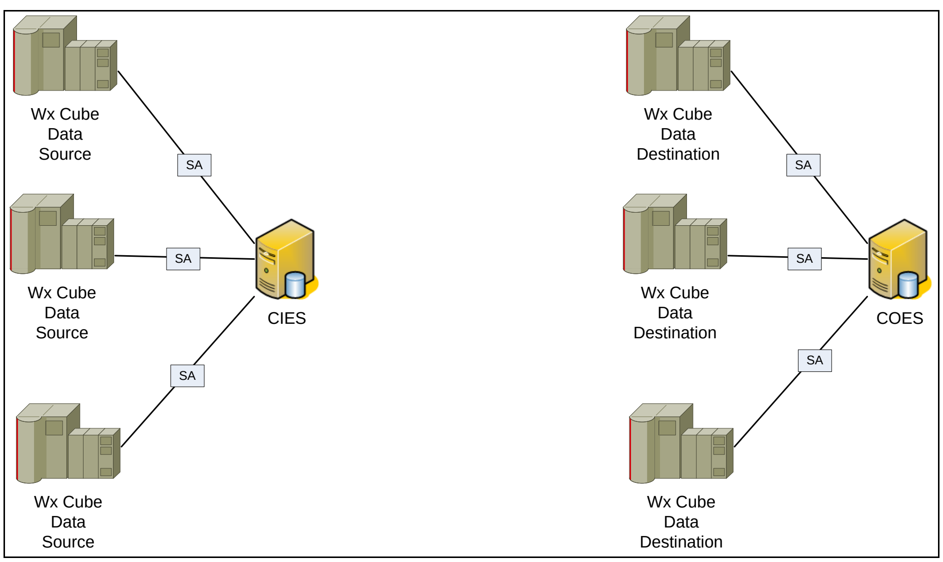
In each case, the COES is composed, in general, of the following:

- System Export Adaptor – Provides an interface to the Wx Data Destination System data and any required export processing
- COES Processing / Storage – Performs the majority of processing required by the COES, as well as the storage management
- Net-Enabled Interface – Supports the interface to the Cube, handling requests.

A more detailed discussion of the functionality contained within the COES is presented further in this document.

6.5.3.3 Hybrid Distributed / Centralized CIES / COES Approach

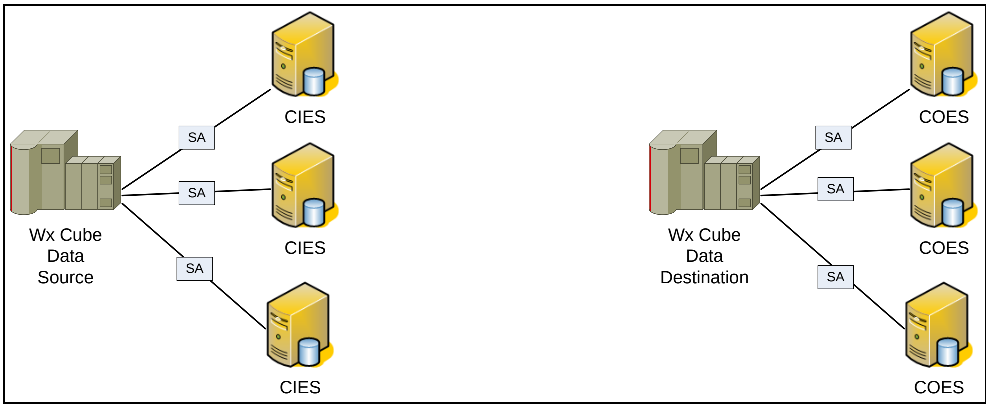
While some Wx Data Source Systems might have their own dedicated CIES to support Cube access to their data, the NOAA architecture concept allows for the pooling of the CIES functionality for multiple Wx Data Source Systems into a single CIES in a more centralized fashion, as shown in the figure below. Similarly, pooling of COES functionality for multiple Wx Data Destination Systems into a single COES may be implemented. This may be necessary if a given data source or destination has not been net-enabled directly, or if demand on a single CIES or COES is so limited they are capable of handling access to multiple source or destination systems.



6.5.3.4 Redundant CIES / COES Approach

As the figure below depicts, to ensure unique (and in some cases, yet to be defined) performance metrics can be met, some Wx Data Source Systems may necessitate that multiple CIESs exist that are serving that source's data to the Cube. This may be required to ensure that if one CIES fails, a redundant CIES can immediately take over without any observed downtime. To ensure adequate site diversity, these multiple CIESs may need to be physically remote from one another. Alternatively, for load handling purposes, multiple CIES may be online constantly to lessen any impacts of degraded performance during peak load periods. Finally, in order to ensure guaranteed service to key data consumers, dedicated CIESs may be made available with access limited to certain data consumers or potential direct access via alternative, dedicated communications means.

Similarly, multiple COES may be necessary if a Wx Data Destination System requires it for any of the above mentioned performance reasons.

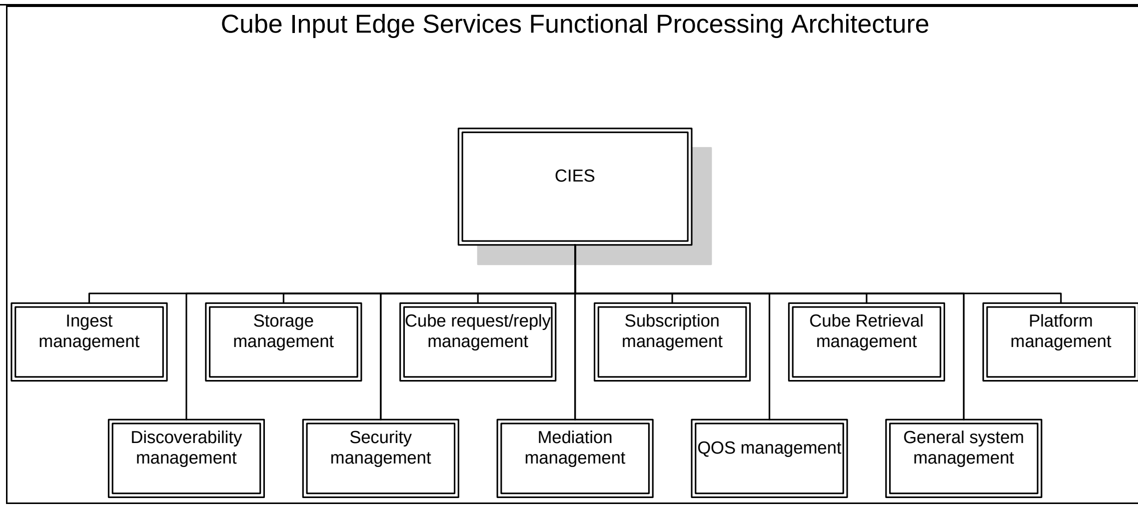


6.5.4 Functional Processing Architecture

The IT System Design document presents the various functions that comprise the CIES and COES and their respective interactions, as well as the interaction between the CIES and the Cube, and the COES and the Cube. This IT System Architecture document presents the supported functionality in a more general sense in the following Functional Processing Architecture discussion of the CIES and COES.

6.5.4.1 CIES Functional Processing

The functional processing supported by the CIES has been derived from the IT requirements presented in an earlier section of this document. An analysis of these requirements yielded the following functionality that defines a CIES.



6.5.4.1.1 Ingest Management

Ingest Management functional processing consists of the following:

- Handles communications between the CIES and the SSA
- Performs ingest processing (and any required translations) of SSA provided data
- Stores ingested data
- Notifies CIES of available SSA-provided data

6.5.4.1.2 Storage Management

Storage Management functional processing consists of the following:

- Provides storage of Cube-available data
- Provides indication of when refreshed subscription data is available for distribution
- Performs pre-processing of data in preparation for common data requests
- Provides access to storage for all ingested and requested data
- Provides data for archival purposes

6.5.4.1.3 Cube Request / Reply Management

Cube Request / Reply Management functional processing consists of the following:

- Handles all requests for storage data
- Translated requests into required filtering / subsetting queries
- Performs required processing before replies are delivered (e.g., compression, re-gridding, map projections, conversions, etc)
- Provides replies for all requests
- Provides notifications that data is available for retrieval
- Handles communications between CIES and requesting nodes

6.5.4.1.4 Subscription Management

Subscription Management functional processing consists of the following:

- Provides for the establishment / modification and distribution of subscription service information to Cube participants
- Manages the tracking of subscription data recipients
- Generates and delivers subscription data upon receipt of fresh subscription data

6.5.4.1.5 Cube Retrieval Management

Cube Retrieval Management functional processing consists of the following:

- Temporarily stores data for subsequent retrieval by Cube requestors
- Handles requests for retrieval
- Manages the retrieval of data from temporary storage and delivery to requestors

6.5.4.1.6 Platform Management

Platform Management functional processing consists of the following:

- Provide self monitoring
- Supports load balancing and redundancy functions
- Handles communications with other CIES to share real-time loading information

6.5.4.1.7 Discoverability Management

Discoverability Management functional processing consists of the following:

- Serves as local storage of metadata
- Handled distribution of metadata to Reg/Rep and in response to requests for metadata
- Handles communications between CIES and Reg/Rep

6.5.4.1.8 Security Management

Security Management functional processing consists of the following:

- Performs all internal CIES security control
- Communicates with Security Services to coordinate security activities

6.5.4.1.9 Mediation Management

Mediation Management functional processing consists of the following:

- Performs all internal CIES mediation control
- Communicates with Mediation Services to coordinate mediation activities

6.5.4.1.10 QOS Management

QOS Management functional processing consists of the following:

- Monitors real-time platform performance
- Provides QOS control information to ensure key services / users get the required service quality

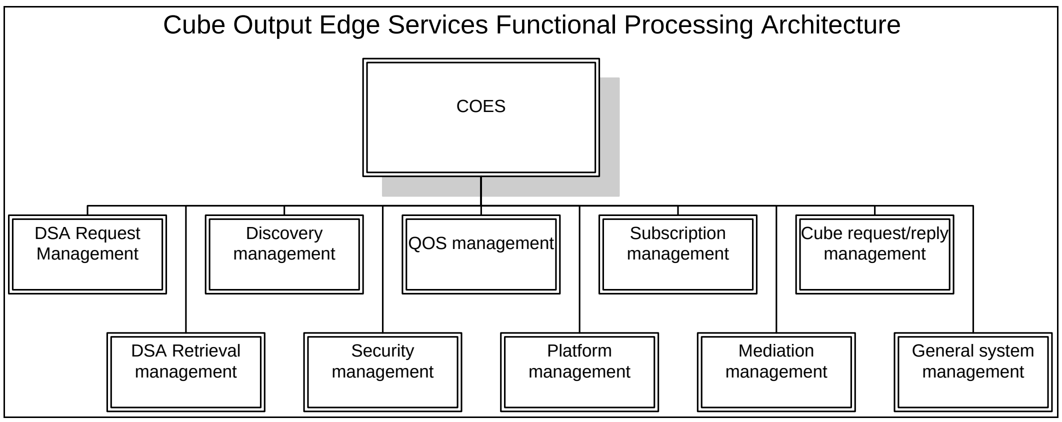
6.5.4.1.11 General System Management

General System Management functional processing consists of the following:

- Handles all logging, reporting, and alarming
- Supports the definition and configuration of CIES
- Provides the mechanisms for backup / restore / update of key CIES software, data, and services
- Provide interfaces to external Administrative Services
- Provides for archival and archival access features

6.5.4.2 COES Functional Processing

The functional processing supported by the COES has been derived from the IT requirements presented in an earlier section of this document. An analysis of these requirements yielded the following functionality that defines a COES.



6.5.4.2.1 DSA Request Management

DSA Request Management functional processing consists of the following:

- Handles communications between the DSA and the COES for all requests for Cube data and returned replies
- Coordinates with other internal COES components to locate the desired data in the Cube
- Returns requested data to the DSA or notifies the DSA that requested data has been obtained by the COES and is available for retrieval

6.5.4.2.2 Discovery Management

Discovery Management functional processing consists of the following:

- Manages queries to the Reg/Rep to identify desired Cube data
- Handles communications between COES and Reg/Rep

6.5.4.2.3 QOS Management

QOS Management functional processing consists of the following:

- Monitors real-time platform performance
- Provides QOS control information to ensure key services / users get the required service quality

6.5.4.2.4 Subscription Management

Subscription Management functional processing consists of the following:

- Delivers requests for subscription data
- Processes changes to information concerning subscription services
- Performs subscription request aggregation

6.5.4.2.5 Cube Request / Reply Management

Cube Request / Reply Management functional processing consists of the following:

- Delivers requests for Cube data and processes resulting replies
- Retrieves data from data source upon notification of its availability
- Handles communications between COES and external Cube data sources

6.5.4.2.6 DSA Retrieval Management

DSA Retrieval Management functional processing consists of the following:

- Temporarily stores data for retrieval by DSA
- Manages requests from DSA to retrieve data stored temporarily
- Handles communications between COES and DSA

6.5.4.2.7 Security Management

Security Management functional processing consists of the following:

- Performs all internal COES security control
- Communicates with Security Services to coordinate security activities

6.5.4.2.8 Platform Management

Platform Management functional processing consists of the following:

- Provide self monitoring
- Supports load balancing and redundancy functions
- Handles communications with other COES to share real-time loading information

6.5.4.2.9 Mediation Management

Mediation Management functional processing consists of the following:

- Performs all internal COES mediation control
- Communicates with Mediation Services to coordinate mediation activities

6.5.4.2.10 General System Management

General System Management functional processing consists of the following:

- Handles all logging, reporting, and alarming
- Supports the definition and configuration of COES
- Provides the mechanisms for backup / restore / update of key COES software, data, and services

- Provide interfaces to external Administrative Services
- Provides for archival and archival access features

6.5.5 SOA-Related Services

Enterprise level information sharing requires a few key services. These services build the foundation for interoperability within the System of Systems enterprise and must be addressed at various levels within the general design. The Information Sharing Environment (ISE) Enterprise Architecture Framework (EAF) has identified the following services as 'core' services. To avoid confusion in this document, these 'core' services will now be termed as SOA-Related services. These SOA-related services include:

- Discovery (search and metadata registration)
- Security (authentication and appropriate access controls)
- Mediation
- Messaging
- Enterprise management
- Storage (e.g. directory services)
- Others

It's important for data, applications, and services to be loosely coupled, and have well defined interfaces to ensure interoperability. This enables the applications and services to be independent of physical implementations and the location of underlying IT infrastructure.

6.5.5.1 Discovery Services Overview

Discovery allows a user to search for and locate existing services and data that can be accessed. Cube participants will publish data and services metadata in a registry to enable all users to find and understand data. Discovery plays a critical infrastructure role and comprises services that:

- Allow for publishing/advertising of service definitions, descriptions, metadata, and accessibility. Information producers may include services, data repositories, devices, and business functions.
- Support discovering service information as advertised by producers.
- Permit discovery, retrieval, and publishing of services without interrupting normal business operations.
- Enable fault recovery via discovery of redundant copies of services.
- Permit discovery services to be integrated at design or run-time to create other composite services.

Services will be discovered via the Registry/Repository. Wellfleet is providing the Reg/Rep for the NextGen Cube that will be used in a federated manner. For NextGen, the federated Reg/Rep will enable aviation users to discover and have access to the complete set of weather products that are in the Cube, regardless of the source. The WellFleet Reg/Rep is based upon the OASIS ebXML Reg/Rep standard. The Registry/Repository service will support the following capabilities:

Capability	Description

Metadata Discovery	Metadata is data used to describe other data. Metadata services provide the ability for enterprise systems to discover and manage (publish, make visible, and access) various metadata products. Services provide the following capabilities: categorizes items into one or more taxonomies, searches for data by multiple criteria (e.g., key words, date, time, submitter), enables communities and users to retrieve and review data based on rankings, provides notification of changed items, allows namespace managers to identify preferred data for their communities, and serves as a clearinghouse for official standards and documents.
Service Discovery	Provides the capability to enable enterprise discovery for publishing, finding, and invoking services/applications registered and categorized in an enterprise information store. Provides integration with other technical capabilities in the foundation, including Enterprise Services Management (ESM) and Security, to support the secure discovery of these services/applications and invokes their use.
Content Discovery	This capability provides a way to perform federated searches for enterprise content (i.e. functional standards, data assets) across federated search-enabled data sources. This capability not only indexes the enterprise content for search, but also provides the ability to search other federated content repositories and exposes the enterprise catalog via a federated search application program interface.

6.5.5.2 Security Services Overview

Security Services provide protection mechanisms to Cube participants (known and unanticipated) users by supporting authentication, authorization, and access control processes to discover data and services on all networks. To secure interactions among enterprise service consumers and providers, the Security Services are defined as services that are standards-based, platform-independent, technology-neutral, and vendor-agnostic. The Security Services category includes components that

- Allow authorized users to access services.
- Enable access control policies to be managed and enforced at the enterprise level.
- Provide developers a mechanism to protect deployed services.
- Include business processing rules that are necessary for enforcing access to protected enterprise service components.
- Leverage existing industry standards and specifications from standards bodies.

The table below summarizes the capabilities that may be offered by the security services category.

Capability	Description
Policy Decision Service	Accepts authorization queries and returns authorization decision assertions. For example, using Security Assertion Markup Language (SAML)
Policy Retrieval Service	Exposes security policies that can be used for service providers to retrieve policies for their resources.
Policy Administration Service	Used by management applications to add, update, and delete authorization policies stored as policy sets.

Certificate Validation Service	Revocation status checking is performed by allowing clients to delegate the certificate validation tasks.
Principal Attribute Service	Provides query and retrieval interfaces to access attributes for users.
Public Key Infrastructure (PKI)	Cryptography protection of exchanged data be required. PKI is a service that may be considered for use to provide public key cryptography. Certificates identify the individual named in the certificate and bind that person to a particular public/private key pair. PKI provides the data integrity, user identification and authentication, user non-repudiation, data confidentiality, encryption, and digital signature services for programs and applications.

No specific security model has been defined yet for NextGen, but such efforts are underway. Security-related services will adhere to inter-agency memorandums of agreements (MOAs), key National Institute of Standards and Technology (NIST) standards, Interconnect Security Agreements (ISAs), etc.

6.5.5.3 Mediation Services Overview

Data and services in an enterprise environment are represented in a variety of formats. Mediation services will help bridge information exchange between data producers and consumers having disparate systems. Mediation services include data transformation and adaptation.

The table below describes the capabilities offered by mediation services.

Capability	Description
Protocol Adaptation	Allows entities in the enterprise to interoperate without either party having to conform to the other's protocols or technologies.
Data Transformation	Facilitates transforming data from one form to another. It also enables translating data between Cube participants, allows support of various formats and supports legacy data throughout the enterprise.

Mediation plays an important role in enabling the exchange of data in different formats. To accommodate the different ways of representing data and the format of the data, mediation services may be used to facilitate the interoperability of different standards used amongst participating organizations. For example, protocol transformation services between JMBL to WFS/WCS and vice versa may be required. Additionally, shared data translation services to convert between data standards (JMBL to WXXM, BUFR to WXXM, and GRIB2-NetCDF4), may be necessary.

6.5.5.4 Messaging Services Overview

Messaging services provide a federated, distributed, and fault-tolerant enterprise messaging capability. These use multiple message brokers, including publish and subscribe, peer-to-peer, and queuing for delivering high performance, scalable, and interoperable asynchronous event notifications to both applications and end users. Messaging also supports the configuration of Quality of Service (QoS) parameters. In addition, it addresses message delivery to disconnected users or applications. Messaging services are built on a message-oriented middleware that may support both asynchronous and synchronous modes of information exchange. Alerts, warning, and notification applications are specific examples that could be built on top of messaging services.

The table below briefly describes specific capabilities that might be offered by messaging services.

Capability	Description
Notification Services	Provides an application interface and the underlying infrastructure to provide users the ability to publish, subscribe, and receive notifications.
Alerts by topic	Provides an application interface and the underlying infrastructure to provide users/systems the ability to publish, subscribe, and receive alerts by topics. Alerts are triggered when a new message is posted by a user or system (asynchronous information exchange).
Enterprise Messages	Provides an application interface and the underlying infrastructure to provide machine-to-machine messaging. The enterprise service/application subscribes to enterprise messages by topics or queues. The enterprise service/application can also publish and receive enterprise messages using this service.

Web Services such as WCS/WFS/WMS/JMBL will be used which have message exchange patterns that support (or will be extended to support) ad-hoc Request/Reply and Publish/Subscribe.

6.5.5.5 Enterprise Management Services Overview

Enterprise Service Management (ESM) is a continuous process of managing, measuring, reporting, and improving the QoS of systems and applications. ESM is the component that provides service management. As the number of services deployed increases, the ability to effectively manage them becomes critical. Monitoring enterprise services allow service providers and service management administrators to collect and evaluate mission critical vital signs such as service performance metrics and QoS data. ESM will integrate with several other service management offerings to provide extensive situational awareness. ESM offers the following capabilities as listed in the table below.

Capability	Description
Monitoring and ensuring QoS of critical components	Generates a report about service health and notifies service providers about any unusual signs.
Monitoring Service Level Agreements (SLAs) compliance	Assists service providers in achieving service promises by monitoring service-level objectives and alerting service providers when service-level objective indicator value gets close to threshold.
Providing detection and handling of exceptions	Enables defining exception conditions, detecting and alerting exceptions, and automatically taking corrective actions to handle exceptions in real-time.
Providing insight into the usage of services	Captures usage data such as service throughput and Service Consumer information, helping with the evaluation of whether a service is useful, worthwhile to continue supporting, and if more services or forwarded staging are needed.
Providing distributed management of services	Offers IT asset managers and service providers the ability to configure, manage, and track distributed services remotely.

Accepting and responding to customer feedback	Provides a means to receive customer feedback and input, and to monitor and resolve issues.

Monitoring the use of services is critical in ensuring the efficiency of the NextGen SOA. Metrics on the overall system performance are important for dynamically updating the system (for example, updating a service) in order to meet the needs of the aviation community. The NextGen architecture will likely provide those capabilities and services listed above to support ESM functionality.

6.5.5.6 Storage Overview

Storage services include capabilities to achieve content delivery and discovery via backup/mirror data stores to support disaster recovery, smart cache methods, and content staging. Storage is maintained independently by each system within the SoS environment. Therefore, the Reg/Rep will be updated accordingly with services to access stored data. Depending on how the service is written, the transaction can be transparent to the user, in that the user would just receive the data they requested, and not realize they accessed stored data. There is no shared storage service envisioned for the NextGen architecture.

6.5.6 Information Exchange

Information exchange details are being developed which address what services are supported by which Cube-participating systems and the data formats for each product provided by these services. This section presents a high level discussion of the potential candidate options. However, more detailed information will be developed over time and documented by the various organizations responsible for developing their respective CIES/COES for their participating system. Additionally, the IT System Design document, a companion document to this IT System Architecture document, will address the proposed data formats for NOAA-provided Cube products and address the Service Interaction Profiles supported by each participating NOAA weather system.

6.5.6.1 Product /Data Formats

To promote compatibility with FAA portions of the Cube, NOAA will support providing data (via CIESs) and obtaining data (via COESs) in the following formats:

- For gridded data
  - NETCDF4/GRIB2
- For non-gridded data
  - WXXM format

Additionally, NOAA will support the exchange of data in the following formats:

- For gridded data
  - GRIB
- For non-gridded data
  - JMBL
  - BUFR?

    - CAP?
- For textual data
    - TBD formats
- For graphical data
    - TBD formats
- For binary data
    - TBD formats

6.5.6.2 Service Interaction Profiles

Service Interaction Profiles (SIPs) establish the basis for interoperability between consumer systems and provider weather services. This interoperability is defined in a number of terms, including messaging formats and message exchange patterns. Additionally, other SIP information must be defined to ensure interoperability.

6.5.6.2.1 Messaging Format / Supporting Web Services

The goal of the overall NextGen Cube project is to make use of existing standards wherever possible. An appendix is provided that addresses many of the relevant standards being considered in the Cube.

6.5.6.2.1.1 FAA Wx Systems

The FAA has decided to build their portion of the Cube around the use of the following OGC Web Services standards:

- WFS – For non-gridded data requests
- WCS – For gridded data requests

6.5.6.2.1.2 NOAA Cube Data Sources

To ensure maximum compatibility with FAA Distribution Servers and Consumer Systems, NOAA's current architecture provides support for CIESs to offer weather data via WFS and WCS services as well. Additionally, the NOAA architecture will support a concurrent instantiation of a JMBL web service for each of its data source systems.

Additionally, NOAA is considering implementing WMS services for providing mapping data where appropriate.

6.5.6.2.1.3 NOAA Cube Data Destinations

In order to obtain Cube data from FAA sources, NOAA COESs require the implementation of either a WFS or WCS client service, depending on the type of data being required (i.e., gridded or non-gridded).

To obtain Cube data from NOAA sources, the NOAA COES requires the implementation of either an OGC-based WFS / WCS / WMS client service, or alternatively a JBML client service.

6.5.6.2.1.4 JMBL / OGC Considerations

It should be mentioned that efforts are underway to compare and contrast JMBL and OGC web services to determine whether NOAA should indeed implement both, or whether the NOAA architecture will rely solely on OGC-based services.

6.5.6.2.2 Message Exchange Patterns

Currently, two primary message exchange patterns are envisioned to be implemented between services.

- Adhoc Request/Response
- Publish/Subscribe

Other patterns are also under consideration to handle Reg/Rep interactions, as well as unsolicited subscription services modification notification and data availability/file retrieval interactions.

6.5.6.2.3 Other Underlying SIP Components

As part of the IT System Design effort, the following SIP components will be addressed:

- Service consumer authentication – how to verify the identity of a requesting consumer systems
- Service consumer authorization – how to determine and assert a consumer system's request to perform certain actions or access certain information
- Service authentication – how the service provides information to a consumer system that demonstrates the service's identity
- Message integrity – how to determine that a message received from a consumer system has not been changed or corrupted
- Message confidentiality – if appropriate, how information in a request from or reply to a consumer system is protected from unauthorized viewing
- Message addressing – recipient, return reply, and possibly third party reply addressing
- Message receipt reliability and receipt acknowledgement
- Service metadata availability and format

7 Open Issues and Risks

A number of open issues and risks may impact NOAA's NextGen IT Architecture and Design. These are sunmmarized below.

7.1 JMBL vs WXXM for non-gridded data & JMBL (SOAP) vs WCS/WFS

NOAA is still in the midst of investigating whether to implement JMBL as its web service and non-gridded data format. The FAA has chosen to implement OGC-based WCS/WFS web services and WXXM as the non-gridded data exchange format. This introduces the potential for incompatibilities between the NOAA and FAA portion of the Cube, including business rules mismatches, format mismatches, etc and impacts the usefulness by NOAA of any of the FAA's RI efforts. The current NWS direction is to assume that access to all data sources provided by NOAA would be via both a concurrent JMBL and OGC-based web service and that mediation between JMBL and WXXM-formatted non-gridded data would need to be performed somewhere (whether by NOAA or the FAA is still an issue). Mediation (conversion) of NOAA provided data not in these formats must also be implemented either by NOAA in the CIES, or FAA in their requesting Distribution Server or a standalone mediation service that the FAA would need to developed and field. This is obviously duplicate effort in standing up both versions of web services and added effort to perform such format translation / mediation.

7.2 Gridded Data Exchange

The FAA is intending on providing all gridded data requested from their sources in NetCDF4 or GRIB2. Any translation from these formats into formats compatible with requesting NOAA systems will be the responsibility of NOAA.

7.3 Use of Oracle as RI Baseline

The FAA RIs are being developed based on Oracle as its native database. NOAA policy strongly encourages the use of open source software to avoid exorbitant costs associated with such COTS SW. Non-Oracle-based RIs may need to be developed before they could be used by NOAA.

One of the current versions of JMBL also uses Oracle as its database as well, so effort would likely be required to develop a non-Oracle-based JMBL implementation as well.

7.4 Decision on Use of RIs by NOAA Data Providers

NOAA must decide whether to make use of the RIs being developed by FAA. Some constraining factors include the use of Oracle as the native database, and the use of FAA-specific FUSE/SWIM technologies as the basis for the RIs, which are not available to non-FAA entities.

7.5 Single Requirement Source

No single source of requirements exists for the IT portion of the Cube. Many of the disparate sources of potential requirements either conflict or are too vague to produce detailed requirements from.

7.6 Textual / Graphical / Binary Products

In the past, the FAA did not have any concrete requirements for the exchange of textual or graphical formatted products within the Cube. The WCS/WFS RIs are not capable of supporting these formats (although there has been discussion the textual products can be encoded in WXXM format at the source and decoded back to text prior to delivery to the requesting legacy system). However, recent FAA efforts have identified that graphical (and text) wx products may be necessary, so corresponding Web Services (e.g., WMS) and supporting formats may need to be defined. There is also questions about whether and how to support binary data exchange.

7.7 Performance Requirements

Performance requirements associated with the IT architecture are sparse or non-existent for many cases, especially for IOC. There appears to be no effort currently defined by the FAA to focus on IT performance requirements. Mention has been made to “use the current performance as a benchmark and do no worse” but effort would be required to determine what these current performances are as well.

The format for defining use cases in the IT Conops document is being changed to create a placeholder to include performance needs associated with each use case, but it is still unclear where these performance criteria will come from.

7.8 Security Requirements / Implementation

Security related requirements are not fully defined at this stage. Initial efforts are underway to better address the security issues associated with the Cube.

7.9 Additional Use Cases to be Developed

More specific and some additional use cases need to be developed to better address the breadth of requirements that must be met by the Cube. These use cases may generate additional requirements for the IT implementation. For instance, additional use cases are being prepared to address:

- Verification
- Cube support for text/graphic products

7.10 NOAANET to FTI Connectivity Concerns

Details of how the NOAA portion of the Cube will connect to the FAA FTI/SWIM environment (and all the associated security concerns) must be addressed.

7.11 Identifying NOAA-Internal Users of Cube Data

Many products and data generated by NOAA are available via numerous systems. For each required Cube product, a decision must be made to identify which specific system will be responsible for providing that product, especially where products might be available from multiple locations / sources.

7.12 Identifying Product & Data Formats and Sizes

A fairly intensive effort remains to jointly agree to data formats and identify expected sizes / volume of each product and dataset that will need to flow through the Cube.

7.13 Handling of Varying QOS and Tiered Access Needs

There will likely be consumers of Cube data that will have very different performance requirements from one another. Some may need immediate (and possibly direct) access, whereas others may have no time critical needs. Both the NOAA and FAA architectures must support this tiered access requirement consistently.

7.14 Pub / Sub Details

Currently, the FAA is considering a Pub/Sub implementation that is tightly coupled to the native capabilities supported with Oracle. There a is strong need to define an Pub/Sub implementation and its respective message exchange that not only allows that interoperability, but is based more standardized WS standards.

7.15 File Retrieval

The FAA WCS RI Gridded data file delivery is intended to be handled as a SOAP message with attachments. The standards allow for a notification that the data is available for retrieval, along with the temporary storage location of the data (which is also how JMBL functions). Additional discussion is necessary to determine if this notification/retrieval approach should be supported as well.